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OBSERVATION OF JAPANESE HIGH-SEAS SALMON GILL-NET FISHERY OFF HOKKAIDO

By C. E. Atkinson*

The salmon runs along the North American Pacific Coast have been exploited for almost a century by the fishermen of Japan, Russia, Canada, and the United States. Originally the fisheries were confined to the coastal waters and the rivers through which the adult salmon must pass during spawning migration. But in recent years, exploitation of the salmon resources on the high seas has been increasing.

On the other hand, in Japan only a limited number of salmon ascend the streams of Hokkaido and northern Honshu and for many years their industry depended upon the lease of shore stations in Soviet Russia.

In 1936 Japanese interests found it difficult to obtain desirable fishing sites in Kamchatka and the Kurile Islands and turned to the high seas in order to sustain their salmon fisheries (Anonymous 1937). The salmon fisheries on the high seas have been described in part by Fukuhara and others (1953), and observations recently made off Hokkaido at the invitation of the Japanese Government provided additional information on the high-seas salmon fishing method developed by the Japanese, especially the importance of water temperatures.

Table 1 - Description of the Research Vessel *Oyasio Maru*

Tonnage	36.4 gross tons
Length	64.0 feet
Width	14.1 feet
Draft	6.4 feet
Engine (Diesel)	120 N. P.
Maximum speed	13½ knots
Crew	13

The author on May 31 and June 1, 1954, accompanied the research vessel *Oyasio Maru*, comparable in size to the commercial fishing boats now operating far offshore. The specifications of the *Oyasio Maru* are given in table 1. As a research boat the *Oyasio Maru* devotes almost its entire effort to determining where fish may be found in abundance and in perfecting means of catching those fish most efficiently. The fish caught are sold to the local markets to help defray the operating costs.

All fishing is done by gill nets made up of a number of single nets, each 80 meters (262.4 feet) long and 6 meters (19.5 feet) deep with a mesh size of 4½ inches stretched. The individual nets are fastened together to form a single gill net which in this case totaled 94 units or about 4¾ miles in length. Only 10 nets were of ramie (a Japanese grass similar in texture to linen) while 84 were of nylon. The nets were hung in a manner similar to that described by Fukuhara.

Drawing on years of experience, the Japanese have concluded that salmon in the ocean are most abundant in areas of rapid temperature change, and prefer temperatures of from 7° to 8° C. (44° to 47° F.). The cruise of the *Oyasio Maru* demonstrates well the importance of temperature to the fishing operation. Beginning at the time of leaving Kushiro, surface water temperatures were taken every half hour, indicating first the location of the cold northern current, then the warmer waters of the "Kuroshio" (fig. 1).

A suitable surface water temperature was found at 4:30 p.m. about 120 miles southeast of Kechiro. The main fishing area was reported by radio to be about 100 miles further offshore (as indicated in fig. 1) in waters of similar temperature conditions.

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*Chief, Pacific Salmon Investigations, Branch of Fishery Biology, U. S. Fish and Wildlife Service, Seattle, Wash.

Note: The author gratefully acknowledges the help of Mr. M. Ohto of the Japanese Fisheries Agency, Mr. T. Myata of the Nippon Suisan Company, and Mr. M. Miyako, Captain of the *Oyasio Maru*, in arranging for this cruise.

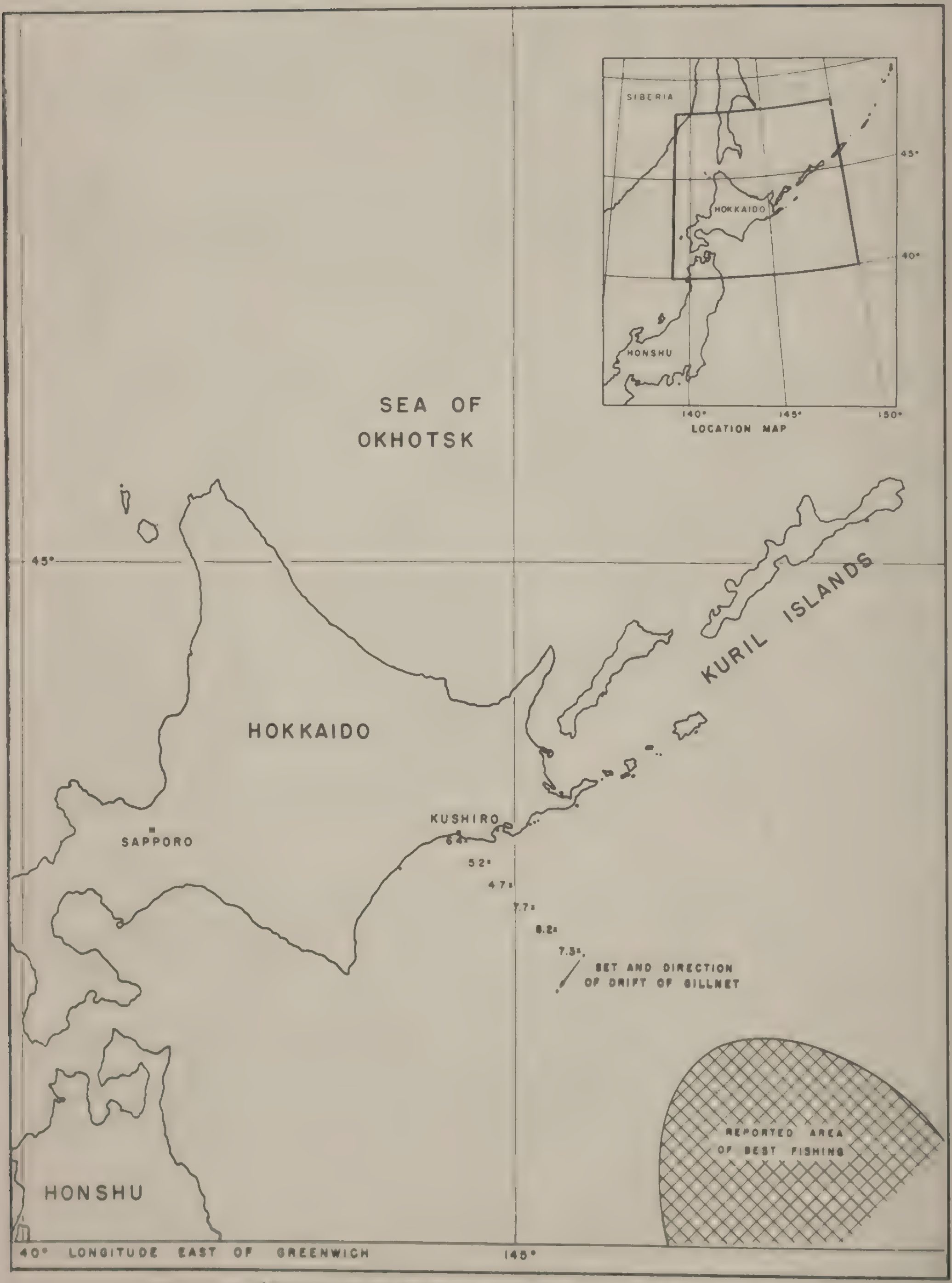
SIBERIA
HOKKAIDO
HONSHU
45°
40°
140°
145°
150°
LOCATION MAP
SEA OF OKHOTSK
KURIL ISLANDS
HOKKAIDO
SAPPORO
KUSHIRO
6.4°
5.2°
4.7°
7.7°
8.2°
7.3°
SET AND DIRECTION OF DRIFT OF GILLNET
REPORTED AREA OF BEST FISHING
HONSHU
45°
140° LONGITUDE EAST OF GREENWICH
145°

Fig. 1 - Map of Hokkaido showing fishing site and relation to surface water temperature.

Vertical temperatures at the fishing site were determined by reversing thermometers. Relatively warm water--6.2° to 7.3° C. (43° to 45° F.)--was found in the upper 15 meters, the temperature becoming much colder--3.2° to 3.6° C. (37° to 38° F.)--at the 25- and 50-meter levels (fig. 2). From vertical plankton hauls, food appeared to be more abundant in the upper warmer layer.

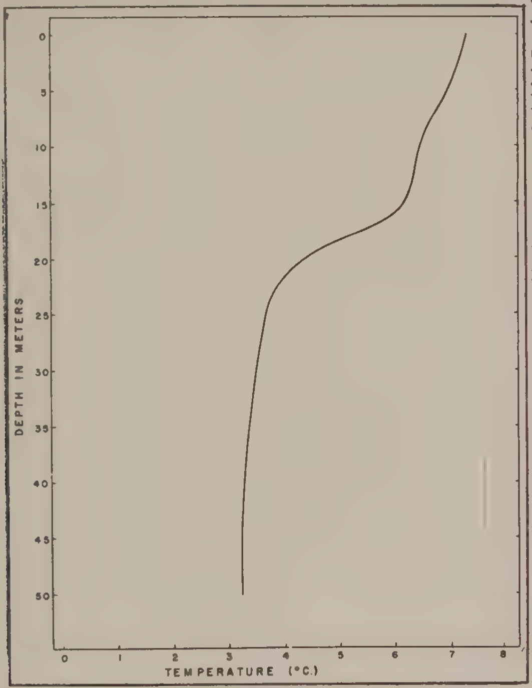

Fig. 2 - Vertical water temperatures at salmon fishing site off Kushiro.

The net, which had been carefully stacked on the rear deck, was set by passing over a roller at the stern while the boat was under way. The net fished from 6 p.m. to 1 a.m.

To lift, two men pulled the net in over the port side of the forward deck immediately below the wheelhouse, one man took out the fish, and two men straightened the net. The net was then passed along the starboard side on rollers to the rear deck where it was carefully restacked. It was nearly 4 a.m. before the operation was complete.

A total of 76 chum salmon and 10 pink salmon were taken during the night's fishing--a catch considered to be quite satisfactory commercially.

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Reprinted from Biological Bulletin, Vol. 107, No. 1, 80–91, August, 1954
Printed in U. S. A.

WATER FILTRATION BY THE BAY SCALLOP, PECTEN IRRADIANS, AS OBSERVED WITH THE USE OF RADIOACTIVE PLANKTON

WALTER A. CHIPMAN AND JEAN G. HOPKINS

Shellfish Laboratory, U. S. Fish and Wildlife Service, Beaufort, North Carolina

WATER FILTRATION BY THE BAY SCALLOP, PECTEN IRRADIANS, AS OBSERVED WITH THE USE OF RADIOACTIVE PLANKTON [1]

WALTER A. CHIPMAN AND JEAN G. HOPKINS

Shellfish Laboratory, U. S. Fish and Wildlife Service, Beaufort, North Carolina

Studies of the movement of sea water through the mantle cavity by lamellibranch molluscs and the efficiency of the gills in removing particulate matter from this flow are of considerable interest to biologists concerned with investigations of the feeding activities of these bivalves. Only through a more complete understanding of the factors controlling the rate of water propulsion, the retention of particles by the gills, and the ingestion of filtered material can we approach problems in the nutritional physiology of these animals.

The rate of water propulsion of a number of species of lamellibranchs has been reported by investigators using either direct measurement techniques or indirect methods based on the reduction of the number of particles in a suspension in which the animals have been placed. Considerable work has been done on the factors affecting the rate of pumping of oysters using direct measurements of the rate of flow following, in general, the experimental arrangement described by Galtsoff, Chipman, Hasler and Engle (1938). The important part of this technique is the use of an "apron" developed by Nelson (1936). In many lamellibranchs direct measurements cannot be made and indirect methods have been widely used. About the first of these measurements that may be considered as truly quantitative was that of Fox, Sverdrup and Cunningham (1937). Their experiments were based on the chemical determination of changes in the calcium content of suspensions of calcium carbonate in which *Mytilus californianus* were placed. The use of plankton in suspension with photoelectric determination of changes in concentration resulting from the activity of the animals was suggested by Jørgensen (1943). Colloidal graphite was used by him in later studies (1949a, 1949b, 1952, 1953) in measurement of conditions affecting the pumping rate of filter-feeding invertebrates and the relation of this rate to metabolic activity. Rao (1953) used these techniques to advantage in his studies on the rate of water filtration of *Mytilus californianus* from different latitudes.

With the availability of methods of labeling plankton cells with radioactive isotopes and the extremely accurate technique of measuring changes in cell numbers based on the detection of small amounts of radioactivity contained in such cells, it seemed advantageous to employ these methods in studies of the filtration rates of filter-feeding invertebrates. Consequently, we have used plankton containing radioactive phosphorus in studies of the rate of water propulsion of the bay scallop, *Pecten irradians* Lamarck, one of the more active species of lamellibranchs, which could lead to further work on the factors concerned with filtration rate and feeding in these and other related marine molluscs.

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[1] The work reported was carried on as a part of a cooperative project of the U. S. Fish and Wildlife Service and the U. S. Atomic Energy Commission. Publication was approved by the Directors of these Agencies.

Materials and Methods

The scallops were collected from the vicinity of the Shellfish Laboratory of the U. S. Fish and Wildlife Service at Beaufort, North Carolina. They varied in size according to their age. They were all of the same year class, spawn of the fall of 1952, and consequently were rather uniform in size for any date of collecting. No very small scallops nor very large scallops were used. The smallest were those studied in June of 1953, and the largest those collected in October, 1953. Spawning of some scallops took place in the laboratory jars starting August 7 and was observed as late as early October. The biology of this species is well covered in a paper by Gutsell (1930).

Observations were made on single scallops immersed in suspensions of plankton cells in sea water. The volume of the suspension was usually 3 liters. With the small scallops a few observations were made in volumes of 1.5 liters, while the largest were tested in 6-liter volumes. The suspensions were well stirred by a stream of air bubbles. It was necessary to fasten the scallops to an L-shaped glass rod to prevent their swimming about. Since the scallop is very sensitive to the movement of an object in the near vicinity, the jars were well enclosed in a wrapping. When not under observation, the scallops were kept in running sea water.

The salinity of the sea water in the laboratory ranged from 31 to 36 parts per thousand, usually being about 34 parts per thousand. Heavy rains accompanying a hurricane in August reduced the salinity to a low of 14 parts per thousand, but no observations were made at the time of low salinity. The sea water used for preparation of the suspensions was aged sea water and plankton-free. It had a salinity of 35 parts per thousand. The scallops were not subjected to any significant change in salinity during the tests.

Observations were made at room temperature, which was held relatively constant throughout the summer and fall. The experimental suspensions ranged from 21.9° to 25.8° C. Variations during any one period of observation averaged 0.50° C., and only twice exceeded 1.0°.

Single species cultures of a diatom, *Nitzschia closterium* (56 microns in length), and a flagellate, a species of *Chlamydomonas* (7 microns in size), were made radioactive from the incorporation of radioactive phosphorus,[2] P^{32}, following the methods developed at our laboratory (Rice, 1953).

It is not difficult to culture many species of phytoplankton so that each cell is highly radioactive. These cells, when grown in enriched sea water containing virtually no phosphorus excepting the carrier-free radiophosphorus, will take up large amounts of the isotope. This isotope is a useful one emitting only β particles of rather high energy and very measurable. Since phosphorus is one of the major nutrients required, the P^{32} will be incorporated rapidly into organic compounds with little remaining in the exchangeable phosphorus of the cells. With rapidly dividing cells grown in this way, there is practically no radioactivity outside the cells in the sea-water medium.

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[2] Obtained from the Oak Ridge National Laboratory on allocation from the U. S. Atomic Energy Commission.

The concentrated phytoplankton cultures, or portions of them, were added to the aged sea water to give the desired cell concentration. The number of cells present after dilution was calculated from measurements of aliquots of the concentrated culture using an improved Neubauer haemocytometer. Changes in the cell concentration of the suspension were followed by radioactivity measurements of aliquots removed at regular intervals. In some experiments samples were taken at various locations in the jar. No significant differences were noted, and the measurements made for each time interval were averaged. Control jars without scallops were sampled in order to measure the rate of settling of the suspensions. Although measurable, settling was so slight as to be negligible. Since the cell population after dilution could be calculated from exact microscope counting, and the radioactivity of the cells accurately measured, any changes in cell population could be detected even though extremely slight. It would be quite impossible to detect such slight changes occurring in short periods of time in dilute suspensions using electrophotometer measurements. In fact the original starting concentration was often lower than that which would give a measurable difference from ordinary sea water blanks using such equipment.

The radioactivity of 10-ml. aliquots of the plankton suspension was measured after the addition of nitric acid to disintegrate the cells and dilution to 25-ml. volumes. A dip type Geiger-Müller (G-M) counting tube was used immersed to a fixed depth in a 50-ml. centrifuge tube and connected to the conventional type scaler. Necessary correction for radioactive decay of the P^{32} was made.

It was originally thought that observations with the G-M tube immersed directly in the suspension would do. However, there was soon an accumulation of radioactive cells around the tube even though it was treated with the non-wetting agent, Desicote. Another objection was the limited time of measurement which might not provide enough counts to give the desired accuracy.

Dilution of the phytoplankton culture with sea water to give the experimental cell concentration was great and very little P^{32} was in the sea water of the suspension. Nearly all the radioactivity was within the cells. However, duplicate aliquots of the suspension were filtered through a freshly-prepared barium sulfate precipitate held on a No. 42 Whatman paper and the small amount of radioactivity of the filtrate averaged and subtracted as an additional background for each observed reading. The preparation of this very retentive filter was described by Rice (1953). Filtration at the end of the observations showed the radioactivity measured was due to the presence of cells.

RESULTS

On being immersed in an experimental phytoplankton suspension, the scallops opened almost immediately and soon started to filter the water through their gills. This resulted in a lowering of the cell content of the suspension. A semi-logarithmic plot of the cell concentrations measured at frequent intervals throughout the period of observations was made to visualize these changes. Figure 1 shows examples of the rate of clearing of suspensions of *Chlamydomonas* and *Nitzschia* cells with different concentrations of cells at the start of the experiments. The rate of clearing varied, but followed the same pattern in nearly all of the tests.

There was a gradual increase in the rate of reduction for a time following the immersion of the scallop. Generally, this took place rather promptly, although in a few instances the decrease in cell number was delayed slightly. This gradual increase in rate of reduction of phytoplankton cells at the start of the observations would be expected since the experiments were started with immersion in the suspension. It was, of course, necessary for the scallop to adjust itself to the new conditions and resume its filtering activities. There was no delay from failure to open as might occur in tests using other lamellibranchs. Normally scallops do not remain closed for any long period.

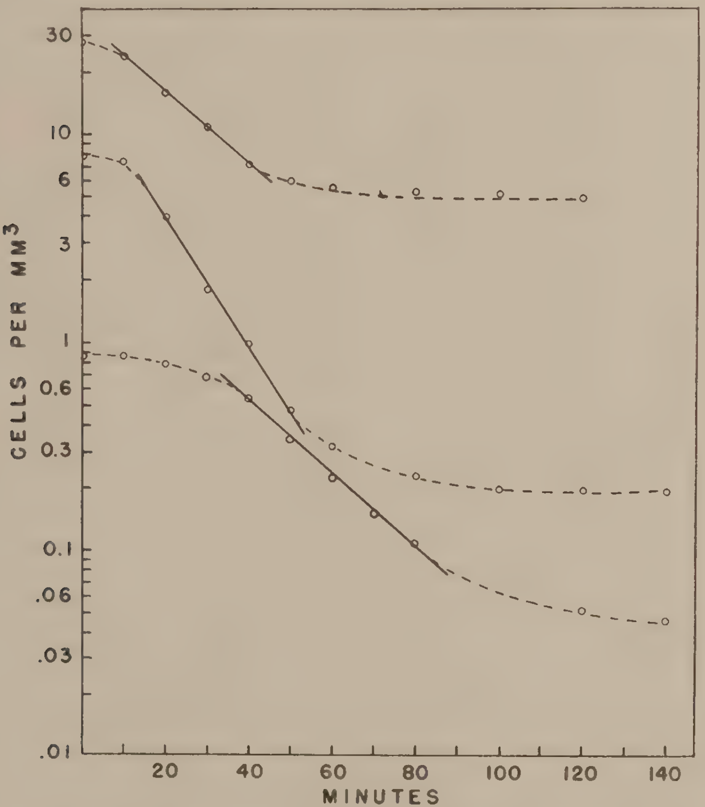

Figure 1. Changes in concentration of phytoplankton cells in suspensions with time after immersion of scallops. Upper curve was with use of *Chlamydomonas* cells, lower two with *Nitzschia*. The solid lines represent the calculated regression lines.

After the initial changes in the rate of particle reduction, a nearly constant percentage decrease of the suspended phytoplankton took place. The regression line for the logarithms of the cell concentrations observed during this decrease was calculated by the method of least squares and drawn for each of the experiments. The solid straight lines of the graphs in Figure 1 represent the calculated regression lines.

The observed points fall very close to these lines. In some instances it was possible to draw a straight line connecting the observed points.

If one assumes that the conditions of the experimental arrangement were satisfactory, the straight line decrease in the logarithm of the cell concentrations with time fits the mathematical equation for a constant rate of water filtration with complete removal of the suspended phytoplankton from the water filtered by the scallop. During this time of complete removal, the observed rate of decrease in cell concentration may represent the rate of water filtration of the scallop. Changes in the rate of clearing of the suspension can be interpreted as resulting from changes in the amount of water filtered. In our experiments it seems likely that the rate of clearing of the suspension was representative of the rate of water propulsion of the scallops during this period of the observations.

As the observations were continued, the decrease in phytoplankton became less and less. This resulted in a flattening of the curves. Although not shown in Figure 1, the number of cells in suspension gradually increased in instances where the observations were prolonged.

There are a number of factors concerned with determining the rate of reduction of particles in suspensions in which the scallops were immersed for observation of their filtering activities. Different ones of these may affect the rate at different times, or more than one factor may be acting at one time. The flattening of the curves of our observations, therefore, may not have resulted from a change in the rate of water filtration.

The decrease in rate of removal was apparently related to time in the suspension. It was not related to cell concentration. Series of observations were made starting the scallops in concentrations of either *Nitzschia* or *Chlamydomonas* at which there was a previous leveling-off in the rate of removal. In each series there was rapid removal followed by a less rapid rate, regardless of the starting cell population. This occurred even in starting concentrations of *Nitzschia* cells of 0.85 per mm.^{3} and in which a leveling-off of the curve took place at 0.04 cell per mm.^{3}.

Incomplete mixing of the filtered water with the unfiltered suspension would result in a decrease in the observed rate of phytoplankton removal that would get less and less as the observations were continued. Changes in the amount of stirring of the suspension in the jar were tried. Even rather violent stirring did not alter the shape of the curves in our experiments. A number of aliquots taken from various locations in the suspension did not appear to differ significantly from each other. Although it is realized that it is virtually impossible to get the mixing required to fully meet the requirement of the mathematical expression giving a straight line decrease, we believe that recirculation of filtered water through the scallop before mixing was not wholly responsible for the flattening of the curves we observed.

The decrease in the rate of removal reflected in the flattening of the curves could be interpreted as a change in the rate of water propulsion of the scallop. However, such a change was not apparent. The scallops were seen to be creating a considerable current of water even when there was no appreciable decrease in suspended plankton. This was also true when the cell concentration of the suspensions increased from a return of phytoplankton cells after earlier removal. It seems not unlikely that the change in the rate of clearing of the suspension was a result of a changed efficiency in the filtering by the scallop, together with a return of cells previously entrapped in the mucus of the gills.

TABLE I

Water filtration rates of scallops

Range in shell length (mm.)	Weight of meats (gm.)	Starting concentration (cells/$mm.^3$)	Liters/hour filtered		Rate per scallop (l./hr.)	Rate per gram (l./hr.)
			Nitzschia suspensions	Chlamydomonas suspensions		
38–44		20		2.3		
		21	4.0			
		23	1.0			
		23		1.9		
		32		3.5		
		32	4.1			
		44	3.4			
		50		5.9		
		56		5.5		
		57		1.0		
Average	3.3		3.13	3.35	3.26	0.99
47–48		23	13.8			
		34	7.8			
		38		6.5		
		44		9.9		
		78	8.0			
		85	3.3			
Average	8.8		8.22	8.20	8.21	0.93
54–56		2.2	14.7			
		4.7	19.3			
		6.4		10.5		
		8.6		13.3		
		11	5.6			
		21	6.7			
		27		3.5		
		31		8.6		
		33		9.0		
		57	8.5			
Average	12.7		10.96	8.98	9.97	0.79
64–65		0.85	9.8			
		1.0	21.6			
		7.9	25.4			
		22	14.0			
		22	16.3			
		22	13.6			
		22	21.5			
		34		6.8		
		38	5.5			
		52	16.6			
		59	10.8			
Average	20.6		15.51		14.72	0.71

If one assumes that the scallop was filtering the suspension efficiently with complete removal of the suspended particles, it is possible to calculate the rate of water propulsion by the application of the formula given by Jørgensen (1943). This is

$$conc_t = conc_0 \cdot e^{-\frac{m}{M} \cdot t}, \text{ or } m = \frac{(\log conc_0 - \log conc_t) \cdot M}{\log e \cdot t}$$

in which M is the volume of suspension in liters, m is the quantity of water moved in liters per hour, while $conc_0$ and $conc_t$ are the cell concentrations at the initial time and after t hours of time. Undoubtedly the rates obtained are not absolute They can only represent an approximation since the original assumption made is not likely to be entirely correct. Escape of the plankton through the gills, if occurring as a fixed percentage of the concentration in the suspension, would not change the nature of the curve but would alter the slope. The measured pumping rate may actually be lower than the true rate.

In our observations we can well assume that the changes in cell concentration in the suspensions represent efficient filtration with complete removal of the suspended cells by the gills excepting for the latter part of the observation times when flattening of the curves took place. We have therefore calculated the rate of water propulsion for the scallops for that time after adjustment to the immersion during which a semi-logarithmic decrease in suspended phytoplankton cells occurred. The rates for observations of different sized scallops immersed in suspensions of *Nitzschia* or *Chlamydomonas* at the various concentrations tested are shown in Table I.

Individual scallops in observations made at different times differed in their rate of filtration, but under like conditions of test the rates were reasonably uniform. The average rates were the same for experiments using either species of phytoplankton for the suspended material. They did not appear to be related to concentration. As the scallops increased in size, their rate of water filtration increased. In June and early July the small scallops averaged about 3 liters per hour. Later during the summer they filtered increasing amounts, and by fall were pumping an average of nearly 15 liters per hour. The maximum rate observed was 25.4 liters per hour for a scallop measuring 65 mm. in length. We did not determine the rate of filtration of the scallops in late fall or early winter when the average size of this year class was somewhat greater.

Although the number of observations was small, the average rate of water filtration per gram of tissue was greater for the smaller scallops than it was for the larger. It is not known what effect the development of the gonads in the late summer may have had on the rate of filtration.

Discussion

The use of radioactive plankton cells for determination of changes in the concentration of cells in suspensions in which a filter-feeding animal is placed is valuable for studies of the filtering activities of these animals. Since the cells can be made very radioactive, it is possible to use very dilute suspensions. It eliminates the need for growing large quantities of plankton in culture for such experiments. The suspensions can be made more comparable to normal sea-water environments. Even in a large volume of suspension in relation to the animal under observation, repeated frequent sampling with the withdrawal of small aliquots is possible. The accuracy of determining radioactivity in extremely minute amounts allows very accurate estimation of cell numbers. No attempts were made in the present study to explore the limits of determination of changes in cell concentrations, nor how few cells in suspension could be measured. However, the radioactivity of the plankton cells used could have been increased considerably, and larger aliquots could have been taken. In all the experiments the aliquots were diluted for radioactive counting and a counter with a rather thick wall (30 mg./cm.^{2}) was used.

The rates of water filtration were measured in cell concentrations well below those that were found by Loosanoff and Engle (1947) to interfere with the pumping activities of oysters. The concentrations used were within those that the scallop might encounter in nature. A short review of the literature on the estimation of phytoplankton abundance in the sea is given by Bainbridge (1953). Galtsoff (1949) presents a discussion of blooming of plankton in the sea. He reports the number of *Gymnodinium* in the surface water in a red tide off Florida as reaching a concentration of 56 cells per mm.^{3}. Cole (1939) measured the phytoplankton content of the sea water pumped into his experimental oyster tanks, and Gaarder and Spärck (1932), Alvik (1934), and Gaarder (1938) report observations for Norwegian oyster pools and fjords. Their values range from 4 to 24 cells per mm.^{3}. Recently, in Great Pond, Massachusetts, a tidal estuary, Hulburt (personal communication) observed a range of phytoplankton from 1.8 to 24 cells per mm.^{3} in carefully counted samples through different seasons. For more open waters, Riley (1941) states that the range he found on Georges Bank from September, 1939 to June, 1940 was from 0.15 to 85 phytoplankton cells per mm.^{3}. Except for most unusual situations, diatoms generally are not as abundant as flagellates and smaller nannoplankton. The importance of nannoplankton in the food-chain cycles of the sea has now become recognized. It is likely that the normal population of diatoms in the sea is about 0.5 cell per mm.^{3} (Hardy and Gunther, 1935). It can be seen that the cell concentrations used in our experiments may not be excessively high, with the possible exception of some in which the diatom *Nitzschia* was employed.

Although the indirect method of measuring the rate of water filtration of lamellibranch molluscs has been used in a number of studies, only in two papers has detailed information as to the changes in the rate of particle reduction during the time of observation been given. Fox, Sverdrup and Cunningham (1937) show data indicating a semi-logarithmic decrease in suspended calcium carbonate with time of observation in experiments using the California mussel. Such a decrease indicates complete removal of the suspended material from the water filtered by the mussels and a rate of filtration relatively constant for the time of measurement. They did observe, however, in certain preliminary experiments a gradual decrease in the rate of reduction with time. This did not take place in later experiments when adequate stirring was provided to minimize the effect of recirculation of filtered water through the mussels.

Jørgensen (1949a) compared the rate of water filtration of the mussel, *Mytilus edulis*, when immersed in suspensions prepared with colloidal graphite, the diatom *Nitzschia*, and three species of flagellates. Changes in the concentration of the suspensions were determined photometrically. The rates of filtration, calculated on the reduction of suspended material, varied with the type of particle used and often changed during the period of observation. In his experiments using graphite particles, there was a gradual decrease in the rate of clearing; the rate at the beginning of the experiments was greater than at the end. In a few observations in which the phytoplankton constituted the suspended material, there was also a decrease in the rate of clearing of the suspensions. For most experiments using plankton cells, however, he found the rates constant or increasing during the tests. In many instances he reports the rate at the end as being greater than at the start.

In our observations on the rate of clearing of suspended phytoplankton cells by the scallop we found, as did Jørgensen for *Mytilus,* an increasing rate of clearing after the start of observations. This was followed by a time during which the rate was relatively constant. However, in our experiments, as we continued the observations further there was a lessening of the rate of removal of phytoplankton cells similar to the change observed by Jørgensen when suspended graphite particles were used. Later, if the observations were still further continued, there was an increase in the number of cells in suspension.

The pelecypods are able to change the efficiency of their gills as a filtering organ. They form a mucous coat over the gill surface which results in efficient particle retention. The importance of the mucous coating in the feeding activity of lamellibranchs has been stressed by MacGinitie (1941). There is also a possible change in pore size by regulation of the ostea of the gills. Galtsoff (1928) observed that a great number of bacteria added to the sea water were not retained by the gills of the oyster. Similar findings of variations in the retention of bacteria by oysters were reported in more recent work using millipore filters (Galtsoff and Arcisz, 1953). Loosanoff and Engle (1947) observed great variations in the numbers of *Chlorella, Nitzschia,* and *Euglena* removed by the gills of oysters at different times. Jørgensen (1949a) interprets the changes he observed in the clearing of graphite suspensions by *Mytilus* as probably due to the change in efficiency of the gill with a stopping of the secretion of mucus if the particles in suspension were unsuitable for food or the animal disturbed. The efficient removal of the phytoplankton cells was explained in the light of an entrapment in the mucous sheet. Jørgensen and Goldberg (1953) present data showing that the graphite particles used in their experiments were retained almost completely in the filtering organs of the lamellibranchs and the ascidians tested.

In our experiments with the scallop, it seems that the changes in the rate of clearing of the suspensions of phytoplankton cells probably were directly related to the efficiency of the gills. There was an apparent complete removal of the cells from the filtered water after the scallops had become adjusted to the conditions of the experiment. It seems likely that there was formation of a mucous coat which allowed complete retention of the cells in the gills. As the experiments progressed, there was a return from the mucus to the suspension of cells previously removed. This return took place in increasing amount. There may also have been a lessening in the efficiency of the gills in removing suspended cells. It would be unwise to ignore entirely the possibility that the conditions of experimental arrangement had no influence on the observed changes in the rate of clearing of the suspensions. It is almost impossible to have the exact mixing of the filtered water with the unfiltered suspension required to present the scallop with the properly diluted suspension each moment.

The filtration rate may not indicate a true feeding rate, for removal of the cells from the suspension may not result in ingestion by the scallop. Considerable work remains to be done on the role of the mucous coat in filtration and feeding activities. The factors concerned with changes in the secretion of mucus and those governing sorting for ingestion of filtered material need further investigating.

The complete removal of the suspended plankton cells from the water filtered by the scallop allows the use of measurements of the rate of particle reduction to serve as a means of calculating the rate of water propulsion. This indirect method is valuable when methods of direct measurement of the flow are not feasible.

There were no apparent differences in the rate of water filtration of the scallops when immersed in suspensions of phytoplankton cells of different concentrations. Loosanoff and Engle (1947) found that the water filtration of the oyster was reduced when exposed to heavy suspensions of micro-organisms. They observed no effects, however, when the concentrations were light and more comparable to those which may be expected to occur in natural marine waters. Although the threshold concentration for effect varied with the size of the species employed, the values found were high. They reported that oysters were able to reduce the population of plankton to concentrations below this threshold rather rapidly in small containers and then were able to clear the suspension normally. It is conceivable that the concentrations used in our experiments exceeded the effective concentration threshold that would interfere with the rate of water filtration of the scallops and the small volume of the suspensions used enabled the scallops to reduce the cell numbers rapidly to a point below this threshold. If such were the case, we would have failed to observe the effects of concentrations above this threshold on the rate of water filtration. It would be possible to increase the volume of the experimental suspension greatly and provide adequate mixing. The scallops then would reduce the population of plankton cells more slowly and be exposed to high concentrations for greater times. The use of radioactive plankton would still allow the measurement of slight changes in cell numbers. It would be interesting to observe if thresholds of cell concentrations affecting the filtration rate existed that were within those concentrations that the scallop might encounter in nature. In low densities the rates were not markedly increased or decreased over those in higher concentrations. This is in agreement with Jørgensen's observation (Jørgensen, 1952) that filtration rates were not influenced by low concentrations of available food in lamellibranchs and ascidians.

In our observations the scallops were found to have a rather high rate of water propulsion. This rate was greater for the larger scallops than for the smaller. Although the large scallops pumped greater quantities of water through the gills than did the small ones, the average pumping rate per gram of tissue in the larger was somewhat less. Our observations were based on a single year class followed as they grew to an age of 12 to 14 months. During this time there was, of course, development of ripe gametes, which may influence the rate as measured for the larger scallops, causing it to be somewhat high. Similar relationships of rate of pumping to size were reported for mussels by Jørgensen (1943, 1949a), Fox, Sverdrup and Cunningham (1937), Willemsen (1952), and Rao (1953).

If we consider the data available, it appears that the adult oyster (*Crassostrea virginica*) of about 4 or 5 years of age at summer temperatures probably has a water propulsion rate of about 12 to 14 liters per hour (Galtsoff, Chipman, Engle and

Calderwood, 1947; Loosanoff and Nomejko, 1946; and Jørgensen, 1952). Although actual data are not available, the oysters used probably weighed somewhat more than 12 to 14 grams. This would mean that the oyster has a rate of water propulsion a little less than one liter per hour per gram of body weight. This is about the rate observed by us for the bay scallop. For the large mussel, *Mytilus californianus*, Rao (1953) shows data indicating that at 20° C. the animals from 30 to 70 grams had a pumping rate of 5 to 6 liters per hour, and a rate per gram of only 0.1 and 0.2 liter per hour. Evidently this animal has a much lower rate of water propulsion than either the bay scallop or oyster. For *Mytilus edulis*, the rates per animal for small individuals at 22° were about 0.16 liter per hour and for larger from 0.3 to 0.4 liter per hour (Jørgensen, 1949a). For large individuals (70 to 80 mm. in length), at temperatures from 11.8 to 14.7° C. an average of 1.8 liters per hour was found by Willemsen (1952). It seems likely that *Mytilus edulis* may have a rate similar to that of *Mytilus californianus*. The cockle, *Cardium edule*, was found by Willemsen (1952) to have a rate of about 0.5 liter per hour for individuals of 30 to 40 mm. in length at temperatures from 17.3 to 19.5° C. This would indicate that sea mussels and cockles have a rate of water propulsion per gram much less than either the bay scallop or oyster.

Jørgensen (1952) has related the filtration rates of several filter-feeding invertebrates to their oxygen consumption. According to his findings there is a quite uniform ratio between the two in all such forms. In view of the fact that the bay scallop has a rapid rate of growth and is a very active animal, it is not surprising that the rate of water filtration is rather high. The oxygen consumption has not been determined, but it is likely to be also high, and may have the same relation to filtration rate that Jørgensen found for related animals.

SUMMARY

1. The water filtration by the bay scallop, *Pecten irradians*, was studied by following the clearing of suspensions of plankton cells that had been made radioactive. The use of radioactivity measurement techniques for such studies of the rate of water propulsion of filter-feeding invertebrates by the indirect method allows detection of slight changes in cell numbers in dilute suspensions and is advantageous for investigation of the feeding activities of lamellibranch molluscs.

2. The scallops were observed to filter the water passed through their gills very efficiently with apparently complete retention of *Chlamydomonas* and *Nitzschia* cells after adjustment to the immersion in the suspensions. The rapid rate of decrease of suspended plankton was not continued, however, for there was evidence of a decrease in the efficiency of the gills and increasing return to the suspension of phytoplankton cells previously removed.

3. The bay scallop has a relatively high rate of water propulsion, probably correlated with its rapid rate of growth and active mode of life. The average rate for small scallops, 38–44 mm. in length, was 3.26 liters per hour. The largest scallops, about 12 to 14 months of age and measuring 64–65 mm. in length, averaged 14.72 liters per hour. The maximum rate observed was 25.4 liters per hour. The smaller scallops had a rate of about one liter per hour per gram of tissue, whereas the older scallops pumped an average of about 0.7 liter per hour per gram.

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Reprinted from Transactions of the Nineteenth North American Wildlife Conference, March 8, 9, and 10, 1954. Published by the Wildlife Management Institute,
Wire Building, Washington 5, D. C.

RESEARCH ON ANADROMOUS FISH PASSAGE AT DAMS

Gerald B. Collins[1]

U. S. Fish and Wildlife Service, Seattle, Washington

The multitude of dams resulting from the development of our water resources for power, irrigation, navigation and flood control is seriously threatening the existence of our anadromous fisheries. If anadromous fish populations are to survive the adult fish returning from the sea must have access to spawning areas. Fingerlings, likewise, must be able to migrate safely to the sea. There are several serious aspects to the problem of fish versus dams, but the most immediate concern is that of providing safe passage at dams for both upstream and downstream migrants.

The Columbia River watershed provides one of the most spectacular examples of the fish passage problem. A series of large dams is planned in the main Columbia and in the Snake River, and lesser dams are proposed in most of the tributaries. Adult fish ascending to their present spawning areas may have to surmount as many as nine dams. Even small losses, injuries or delays at each dam could prevent spawning and result in decimation of the run. The small fish migrating downstream to the sea will also have to run this gauntlet of dams, and, because of the cumulative effects of such a series of hazards, relatively minor losses at each dam could jeopardize the entire fishery. If the fishery is to be protected, the passage of both adult fish and fingerlings must be achieved with the maximum efficiency.

The problem is urgent! There are already two major dams on the Columbia without fish passage facilities. These dams, Grand Coulee and Chief Joseph, cut off over 1,000 lineal miles of streams that were formerly available to salmon. This was not done through neglect, but because we were unable to provide an economically practical solution to the problem of fish passage at high dams. Plans and preparations are in progress for many other dams, and time, so badly needed for research, is growing shorter. The fate of the once-abundant runs of salmon and shad on the East Coast provides a grim reminder of the price of delay or failure in seeking the necessary answers.

Fishery agencies on the West Coast, well aware of the critical nature of the problem of fish passage, are expanding their research in an all-out effort to solve the problem while there is yet time. The personnel and facilities of colleges and universities are being enlisted in the search for ways and means of getting fish safely past dams. The U. S. Army Corps of Engineers, as a major dam building organization, is providing funds for a broad program of ''Fisheries-Engineering'' research directed toward an economic solution of their fish passage problems in the Columbia River. In both the United States and Canada, fishery agencies are pooling information and coordinating research programs in an effort to insure that no promising possibility remains unexplored.

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[1] In the absence of Mr. Collins this paper was read by Dr. Herbert W. Graham.

DOWNSTREAM MIGRANTS

A major part of the research effort will be directed toward that aspect of the fish passage problem which appears to be most difficult to solve—the protection of the downstream migrants. The migrating fingerlings move downstream following large water flows into diversions, turbine intakes and under spillway gates. Injuries and losses are often difficult even to measure and at this point of our knowledge, almost impossible to prevent. Mechanical screening has been used successfully at small installations but is impractical for the huge volumes of flow at large dams. There is need for an inexpensive method by which fingerlings can be directed away from dangerous areas into bypasses that will transport them safely below dams.

Experiments are being conducted both in the laboratory and in the field, examining the use of a wide variety of stimuli to direct the salmon fingerlings. These exploratory tests involve the use of electricity, lights, sound, odors, screens of air bubbles, dyes, louvers and other mechanical deflectors. At the moment, the most promising approaches appear to be in the use of electricity, lights and louvers.

The use of electric fish screens is not new, some installations having been in use for over 30 years. Most of such applications have endeavored to establish an electrical field as a barrier or ''fence'' to prevent the entrance of fish into a given area, the fish being repelled by the electrified area. These electric screens have generally proved to be unsatisfactory with migrating fish and particularly so with downstream migrants. The fingerlings seem unable to avoid the electrical field where they are stunned or even killed rather than diverted. In our present research, attention has been turned toward the use of the directional properties of electric fields. When fish are subjected to a field of pulsating direct current, the fish tend to move toward the anode. The experiments now in progress are attempting to take advantage of this electrotaxis in guiding fingerlings. Instead of attempting to repel the fish, the field is designed so that the fingerlings enter the field and are then oriented in the desired direction.

The use of electricity in guiding fingerlings is being approached cautiously, however, for while electricity can control the movements of fish, it can also injure or kill them. The voltage gradients necessary to affect the movements of small fish are frequently dangerous for large fish. This creates a complicated problem, for at some locations there are times when fingerlings of several sizes and species are present as well as large adult upstream migrants. A solution to this situation is being sought in electrical fields with progressively increasing zones of voltage gradients that will affect larger fish first, directing them out of the area before they can enter the voltage zones necessary to direct the small fish. As experiments proceed investigating the wave forms, pulse frequencies, pulse durations, voltage gradients, current densities, and field patterns most effective in directing fingerling movements, parallel experiments explore the ranges of these same charactristics that may be injurious to the fish or that might modify normal reactions temporarily in such a way as to affect their survival. Long-range experiments are also in progress to test the possibility that exposure of fingerlings to an electrical field might affect their future reproductive ability.

The application of the principle of electrotaxis to the problem of protecting downstream migrants has much promise, and it is being investigated on a large scale by several research agencies. However, the method will require a detailed knowledge of the relation between the electrical energy levels producing electrotaxis and those with detrimental effects on the fish.

The use of phototaxis in directing fingerling movements is also not new. Experiments in which lights have been used in various ways to either attract or repel fingerlings have met with varying degrees of success but never with enough to justify their general application to the problem of fish protection. However, laboratory and field tests now in progress once again are calling attention to the extreme sensitivity of young salmon to light. It is hoped that with an increased knowledge of the nature of this phototactic reaction a more successful application can be made. Current research interest centers upon the use of a barrier of light, sharply defined on the upstream side, located diagonally across the direction of stream flow to deflect the fingerlings, taking advantage of their reluctance to pass into an area of higher light intensity.

There are serious obstacles to be overcome in developing a satisfactory technique utilizing light as the guiding stimulus. One of these is the problem of making such a method function satisfactorily in the daytime. Although our present information seems to indicate that the largest part of fingerling downstream migration is at night, a technique that was ineffective in daylight hours could only be looked upon as a partial solution. The avoidance of the light deflector at night might result only in the delay of the normal downstream movement of a large part of the fingerlings until daylight. The excessive turbidity of many of the streams concerned may also make application of a light technique very difficult. The great advantage of a method of guiding fingerlings with light, and a strong incentive to expend every effort to develop such a technique, is that the method would not involve the danger of injury to the fish that is ever present in electrical and mechanical methods and the method would have the further advantage of a minimum of interference with water flow.

A third technique showing promise as a means of collecting migrating fingerlings from a large volume of water is the use of louvers. The louver screen consists of a series of vertical baffles or louvers placed diagonally across the stream flow with a bypass located on the extreme downstream end. Fingerlings seem reluctant to pass through the narrow openings between the louvers and are thereby deflected into the bypass. Experiments with the use of a louver screen now being conducted at a large water diversion at Tracy, California, indicate that this type of screen is equally effective by day or night, and the experiments show very little evidence of any injury to the fish. The chief disadvantage of this technique appears to be in a large structure of louvers required, which, from the standpoint of initial cost, maintenance and interference with flow, probably limits its usefulness at major dams.

While all of the methods for guiding fingerling so far explored seem to have limitations, it must be borne in mind that most of this research is still at a preliminary stage. If a general solution to the problem of directing fish that will be applicable to all situations and circumstances, all sizes and species of fish is not found, the problem of fingerling passage might still be solved satisfactorily by applying a variety of techniques, each adapted for a particular set of conditions. It is of the greatest importance, therefore, to examine carefully every potential method for its possible use even in restricted circumstances, not only alone, but in combination with other methods.

UPSTREAM MIGRANTS

By comparison to the problems involved in providing safe passage for downstream migrants, the task of passage facilities for upstream migrants seems relatively easy. Yet, we have little reason to feel complacent about our knowledge relating to passage of adult fish. There is evidence that our present fishways are oversize, inefficient and far too expensive. The reduction of fishway costs is becoming increasingly important to the protection of the fishery resource. The cost of construction and maintenance of fishways has now reached such proportions that many people concerned with river development policy are beginning to ask if the value of the fishery warrants such expenditures. For example, the estimated construction cost of fishways at six new dams planned on the Columbia River is in excess of $100,000,000, with the maintenance and operation costs estimated to be more than $1,000,000 annually. Precedents have already been established on the Columbia River for dams without any facilities for fish passage. An important part of the research on adult fish passage will be concerned, therefore, with finding more economical methods for providing adult passage.

The high cost of fish passage facilities can in many cases be traced directly to a lack of definite knowledge on fish behavior and of the principles involved in fish passage. This lack of information is reflected in fishways designed with huge safety factors in size and auxiliary flows, and, in the expensive provision made for duplication of facilities (*i.e.*, both fish-ladders and fish locks at major dams.)

To provide a means of acquiring the information a special type of laboratory is being planned in which it will be possible to measure the reactions of the migrating fish under controlled experimental conditions. The structure will be located on a bypass into which fish can be diverted from one of the major fishways at Bonneville Dam. The fish will swim into the laboratory where they can then be subjected to a variety of experimental conditions without interfering with the normal passage of fish in the main fishway. When the fish have passed through the experimental area and their reactions are recorded, they will swim out of the laboratory and reenter the fishway. Experiments are planned investigating the swimming abilities of the fish, their reactions to light, form, water turbulence and spatial relationships. An effort will be made to discover the factors controlling their rate of movement through fishways and the size of fishway required for given numbers. By the use of choice techniques the preferences of the fish for various flow properties, water temperatures and chemical conditions will be measured. The behavior of fish in tunnels and conduits, open channels and pools will be examined using the actual full scale dimensions and flows used in fishways at major dams. The construction of this unique type of laboratory will make possible an entirely new experimental approach to the problem of fish passage.

PRINCIPLES OF FISH PASSAGE

As intensive efforts to solve fish passage problems get under way, one point becomes increasingly clear—that, although our concern is for the application, little progress will be made until we have an understanding of the basic principles involved. What are the principles involved in providing passage for fish? The answer will only be found in the behavior of fish. Whether the problem is—How to attract adults into fishway entrances without delay? How to collect fingerlings to prevent them from entering dangerous areas? How to design bypasses? or, How to disperse fingerlings at bypass exits to reduce predation?—all of these require an intimate knowledge of the factors influencing the direction and rate of fish movement. The biological term for this aspect of fish behavior is fish orientation. It includes all of those reactions that determine the position and movement of the fish in relation to its sourroundings. Principles of fish orientation are the basic principles involved in providing passage for fish. A systematic search for the principles of fish orientation may provide the shortest and surest route to a solution of the problem of fish passage at dams.

CIRCULATION IN A MERIDIONAL PLANE IN THE CENTRAL EQUATORIAL PACIFIC

By

TOWNSEND CROMWELL

Pacific Oceanic Fishery Investigations
U. S. Fish and Wildlife Service

ABSTRACT

Meridional sections of σ_t, salinity, inorganic phosphate, and dissolved oxygen, based on new data from the central equatorial Pacific, show evidences of upwelling near the equator. An Equatorial Front in the ocean surface layer is described. Sinking occurs along this front, which is found most often just north of the equator. Reasons are advanced for the existence of horizontal convergence and sinking in a region slightly to the north of the equator during southeast tradewinds when no front is present. Horizontal divergence and convergence apparent in a qualitative model of horizontal flow near the equator seem to be important in producing vertical motion. The circulation in a meridional plane in the surface layer is discussed, with strict adherence to the principles of isentropic analysis. The role played by the circulation in supporting a large population of zooplankton and fishes is discussed.

INTRODUCTION

Currently the U. S. Fish and Wildlife Service, through its Pacific Oceanic Fishery Investigations program (POFI), is investigating the tuna resources of the central equatorial Pacific Ocean (Sette, 1949). Since knowledge of the ocean circulation is basic to an understanding of such a study of productivity, the program includes an investigation of the physical and chemical environment. From January 1950 through August 1952, the Hugh M. Smith occupied 365 hydrographic stations comprising a number of sections across the equatorial current system (see Fig. 1).

Measurements of the following were made at sea: temperature, using deep-sea reversing thermometers; inorganic phosphate, using the Automatic Servo-operated Photometer (Snodgrass, et al.); and oxygen by the Winkler titration. Water samples were taken to the Honolulu laboratory for chlorinity determination by the Knudsen method. Part of the large amount of hydrographic data collected has been examined in an attempt to determine the circulation in a meridional plane across the major equatorial currents.

Defant (1936) has described a model which he suggests illustrates the basic features of the meridional circulation of the tropical Atlantic, and Sverdrup, et al. (1942) and Sverdrup, et al. (1944) have stated

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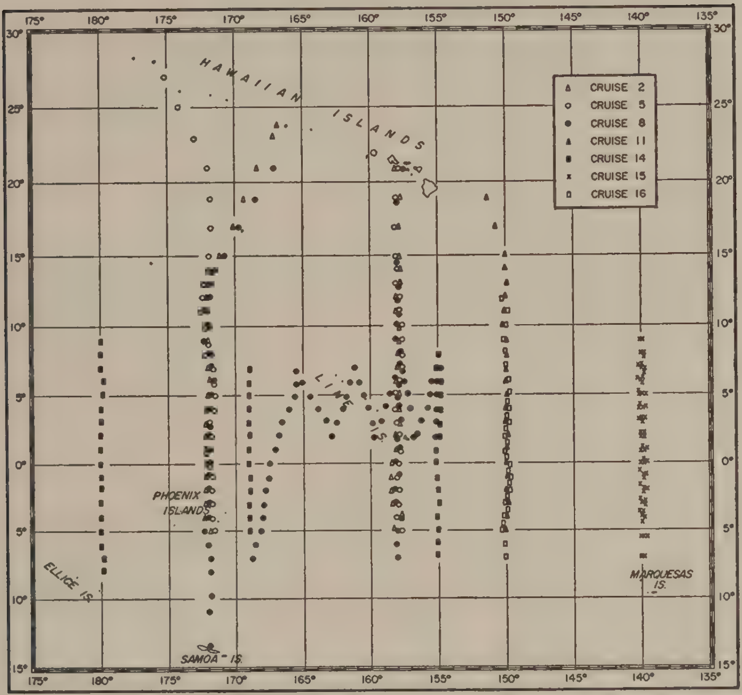
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Figure 1. Positions of 365 hydrographic stations occupied by the M/V Hugh M. Smith during seven cruises to equatorial waters. The cross sections of Fig. 2 are based on cruise 2 stations (Δ) along primarily 172° W Long. Those of Fig. 3 are based on cruise 5 stations (○) along 158° W Long.

that the same circulation exists in the Pacific. Montgomery (1938) has raised serious doubts that a circulation of the type they describe exists in the tropical Atlantic and Pacific. He has demonstrated the importance of isentropic analysis of flow in the ocean and its application to the meridional circulation. The qualitative discussion which follows is intended to adhere rigorously to isentropic principles.[1]

Our data were examined first for evidence of vertical motion. The regions of upwelling and of sinking are revealed on cross sections like those shown in Figs. 2 and 3.

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[1] In this paper the principles of isentropic analysis are applied to flow on surfaces of constant σ_t. For a discussion of the degree of inadequacy of σ_t surfaces to represent surfaces along which sea water flows, see Montgomery (1938: 11–14).

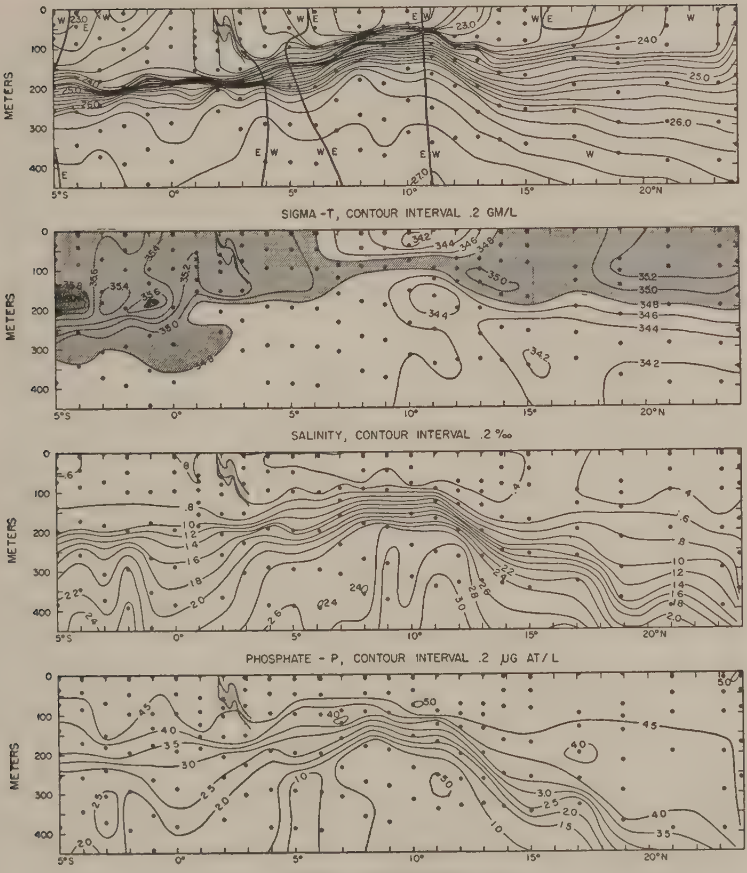
HORIZONTAL DIVERGENCE AND UPWELLING

The dense surface water that appears near the equator (Figs. 2 and 3) contrasts strikingly with adjacent surface water and suggests upwelling. Charts of sea surface temperature, such as those of Schott (1935) and Sverdrup, et al. (1942), show this feature as a band of cold water along the equator that decreases in prominence toward the west. This meridional contrast may be maintained in part by a strong west current at the equator, as drawn by Schott (1935), the water from the east being relatively dense. This does not seem to be the entire explanation, however, since the high concentration of inorganic phosphate in this dense water probably cannot be explained on the basis of horizontal flow from a source of nutrient-rich surface water at even the closest land to the east. At 50 miles per day it would take approximately 80 days for a parcel of water to reach the central Pacific from the Galapagos region, and during this time it is likely that the phytoplankton would deplete the inorganic phosphate were there not a continuing renewal from below.

Kinematically, this renewal clearly can take place along σ_t surfaces. The $\sigma_t = 23.60$ surface, which in Fig. 2 intersects the sea surface at two points near the equator, submerges both northward and southward into the thermocline. Meridional flow along this surface in either direction would bring water from the region of the thermocline to the sea surface near the equator. Thus, referring again to Fig. 2, flow of water which lies between the surfaces $\sigma_t = 23.60$ and $\sigma_t = 23.80$ may be likened to flow through a conduit that broadens vertically near the equator. Water within this layer which nears the equator from the south rises to the surface, its nutrients becoming available to plants in the euphotic zone. Further, some of this water may leave the euphotic zone, submerging as it continues northward within the "conduit." Vertical motion, then, can go on continuously with flow along σ_t surfaces and a stationary distribution of mass. Like most analogies this one should not be carried too far, however. Flow actually occurs through the "conduit walls," i. e., across surfaces of constant σ_t, as will be described later.

The same general features of density distribution that appear in Fig. 2 appear also in Fig. 3, although a pocket of relatively light water centered between 2° and 3° N complicates slightly the picture north of the equator.

There are several tongue-like features on the cross sections, particularly in the salinity distributions. Little information about flow can be inferred from these features, however, without information about the mixing processes which may be of major importance in maintaining



SIGMA -T, CONTOUR INTERVAL .2 GM/L

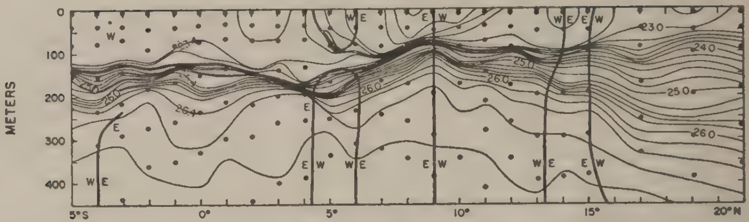
SALINITY, CONTOUR INTERVAL .2 ‰

PHOSPHATE - P, CONTOUR INTERVAL .2 µG AT/ L

OXYGEN, CONTOUR INTERVAL .5 ML/L

Figure 2. Cross sections of σ_t, salinity, inorganic phosphate, and dissolved oxygen along primarily 172° W (see Fig. 1) based on observations by the M/V Hugh M. Smith, January 26–February 8, 1950. Dots indicate positions of observations. Shaded zone in surface layer is a front. Boundaries between east-flowing (E) and west-flowing (W) currents, as determined by dynamic calculations, drawn on σ_t cross section outside the 3° parallels.

them. A case in point exists in the vicinity of the Countercurrent. Here tongues of high-salinity water pointing from the north and south are joined by a narrow neck of somewhat less saline water. This layer is one of maximum salinity in the vertical distribution, separating still fresher water below the thermocline from that in the surface layer.



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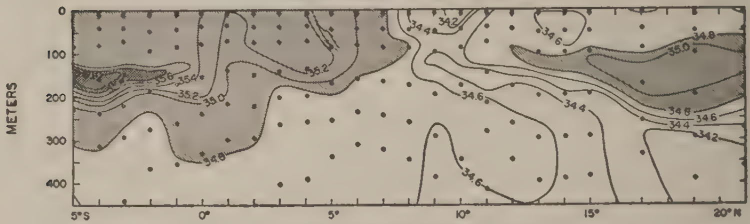
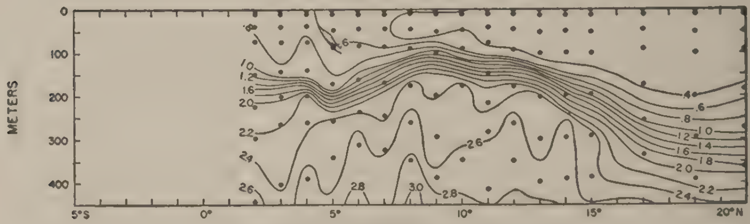
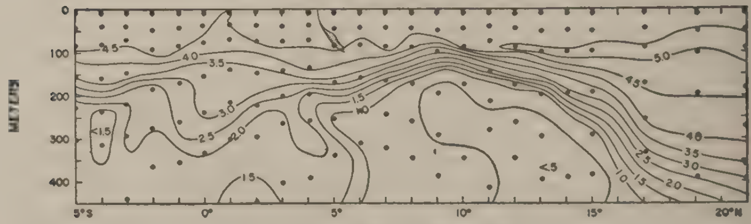


SALINITY, CONTOUR INTERVAL .2 ‰



PHOSPHATE - P, CONTOUR INTERVAL .2 µG AT/L



OXYGEN, CONTOUR INTERVAL .5 ML/L

Figure 3. Cross sections of σ_t, salinity, inorganic phosphate, and dissolved oxygen along 158° W (see Fig. 1) based on observations by the M V Hugh M. Smith, July 28–August 6, 1950. Dots indicate positions of observations. Shaded zone in surface layer is a front. Boundaries between east-flowing (E) and west-flowing (W) currents, as determined by dynamic calculations, drawn on σ_t cross section outside the 3° parallels.

This distribution can be maintained by mixing processes alone, the loss of salt vertically by diffusion from the neck being balanced by a replenishment due to lateral mixing.

The saline layer in the upper part of the thermocline that originates far to the south of these sections (Defant, 1936) ends abruptly near the equator, giving the appearance of saline tongues in Figs. 2 and 3 (albeit somewhat less clear-cut in the former figure). Whether this saline layer extends to the equator by virtue of a current or lateral mixing cannot be demonstrated here, but its abrupt termination near the equator is consistent with upwelling. The high-salinity water in the upper part of the thermocline that is carried upward by upwelling will be mixed with waters of the turbulent surface layer, and the saline layer mixed away.

There is no evidence of significant upward motion anywhere along the sections except near the equator. In general the surface layer consists of warm light water of low inorganic phosphate concentration, characteristic of water that has been near the surface for a considerable time. The σ_t surfaces are not so oriented that flow along them could renew the surface layer, as can occur near the equator.

In particular, there is no evidence to support the suggestion by Defant (1936) and Sverdrup, et al. (1942) that there is upwelling at the boundary between the North Equatorial Current and the Countercurrent. Although more than one east-flowing current is indicated on the σ_t sections, the dynamic calculations indicate a major countercurrent with its northern boundary near 10½° N and 9° N, shown respectively on Figs. 2 and 3. The thermocline is relatively near the sea surface along this boundary because of the "geostrophic effect," i. e., because of the dynamics of a steady current in the northern hemisphere which requires that dense water be found along the left boundary. It does not follow, of course, that upwelling is occurring or that it need occur at all to maintain this mass distribution. Because of the shallow position of the thermocline along this zone, however, nutrient-rich water may on occasion reach the surface as a result of wind stirring or through the direct absorption of radiant energy, which would allow upward motion across σ_t surfaces. Occurrences of the former would be sporadic, during excessive winds, and upward motion due to the latter would be slow, since little radiation penetrates to the thermocline. Probably neither process is of comparable importance to that of upwelling in adding nutrients to the surface layer in the central Pacific. Our hydrographic cruises have revealed that the surface layer near the Countercurrent boundary is nutrient-poor (Figs. 2 and 3).

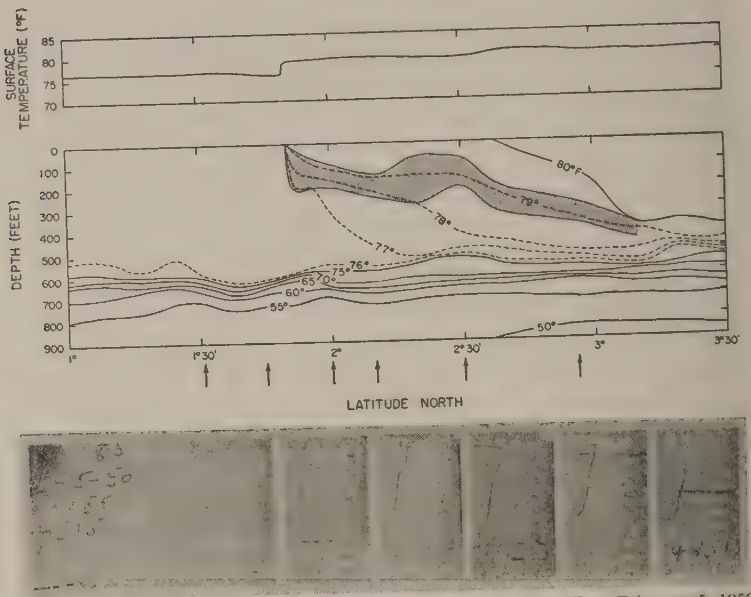


Figure 4. Thermal structure of the Equatorial Front at 172° W on February 5, 1950. Uppermost curve is surface temperature showing frontal discontinuity at 1° 50′ N (also see Fig. 5). Middle diagram, showing subsurface thermal structure, is an enlarged view of a small part of the cross section of Fig. 2. The frontal zone is shaded. Note that the vertical exaggeration (≑ 300 : 1) gives rise to an apparent thickening of the frontal zone below the sea surface. The arrows indicate positions of the six BTs which are reproduced in the lower part of the figure.

HORIZONTAL CONVERGENCE AND SINKING

On several occasions (including the station lines on which Figs. 2 and 3 are based) our vessels crossed a pronounced oceanic convergence or front near the equator. In Figs. 2 and 3 this Equatorial Front appears as a shaded zone in the surface layer just north of the equator. It does not occur at the boundary between the Countercurrent and the South Equatorial Current. The thermal structure of the front that appears in Fig. 2 is shown in detail in Fig. 4. It is well defined by the continuous horizontal and vertical temperature records. North of its intersection with the sea surface it is revealed by BTs as a stable zone within the surface layer. The actual surface thermograph record, showing a near discontinuity at the front, is reproduced as Fig. 5.

Besides the front that appears in Fig. 3, there were indications of a second front at about 1° 45′ N, between the pocket of relatively low

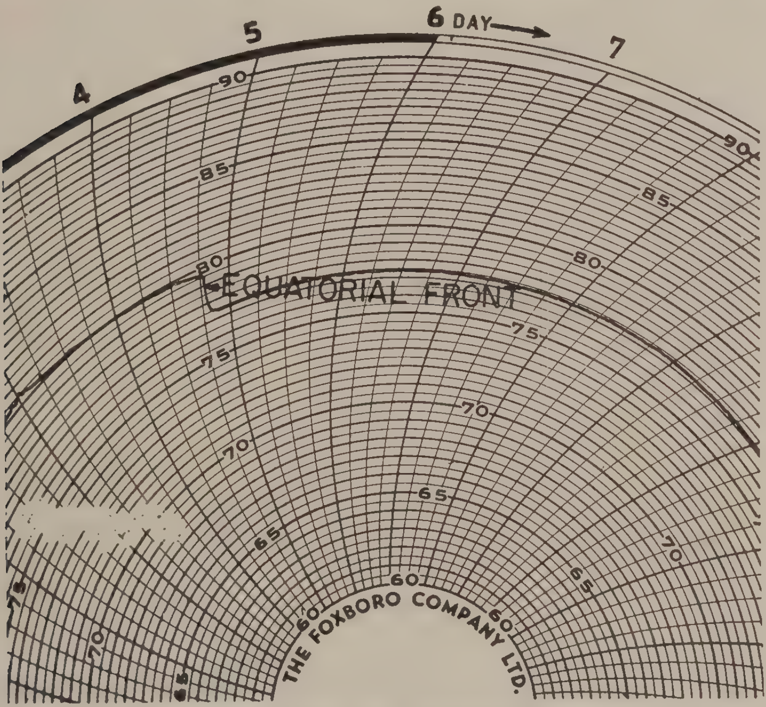


Figure 5. Thermograph trace showing near discontinuity at the Equatorial Front at 4:47 p. m., L. S. T., February 5, 1950.

density water near 2–3° N and the dense water centered near the equator. The second front is not drawn because it is barely discernible in the BTs.

How the front is formed is not known, but the maintenance of such an intense temperature gradient indicates a continuous renewal of the water types on one or both sides of the front.

The BTs in Fig. 4 show striking homogeneity in the dense water immediately south of the front. Vertical turbulence would be virtually unimpeded in this water, and there is evidence to support the thesis that such turbulence is actually going on. For example, the BT traces show a sharp "corner" at the bottom boundary of the homogeneous surface layer. This characteristic of the trace along with the concentration of gradient in the upper part of the thermocline would be eliminated were it not maintained by some active process, presumably by turbulence.

The existence of this homogeneous region suggests that some water that sinks beneath the front returns equatorward in the lower part of the surface layer. This would complete a cellular circulation in the meridional plane, with ascending flow near the equator, sinking near the front, surface flow towards the front, and equatorward flow below. Disregarding the effects of external factors which act to alter the density within the cell, the latter can exist only in homogeneous water and still be consistent with principles of isentropic flow.

Although a distinct Equatorial Front is not common in the central Pacific, the thermal structure of the surface layer near the equator is usually complex, indicating the simultaneous existence of possibly two or three indistinct fronts, in the process of formation or dissipation.

When the Equatorial Front is not present there seems to be no way of demonstrating convincingly with cross sections that sinking is or is not occurring. There is some theoretical basis for expecting horizontal convergence and sinking north of the equator during southeast tradewinds, and this will be discussed later.

QUALITATIVE THEORETICAL CONSIDERATIONS

The complete hydrodynamic expression for horizontal motion equates the acceleration to the vector sum of the horizontal components of the following:

(1) the Coriolis force (the deflecting force due to the earth's rotation) per unit mass,
(2) the pressure-gradient force per unit mass,
(3) the frictional force (resulting from viscous and eddy stresses within the ocean and the wind stress at the sea surface) per unit mass.

Ekman (1905), who described in detail the current that would be produced in a deep, homogeneous, unbounded ocean by a wind stress at the sea surface, assumed that this stress is balanced entirely by the horizontal component of the Coriolis force. The steady-state transport of this "wind drift current" is directed one right angle *cum sole* from the wind direction (i. e., to the right of the wind direction in the northern hemisphere, to the left of the wind direction in the southern hemisphere). For a given wind stress the magnitude of the current is inversely proportional to the sine of the latitude. Thus, a given wind stress directed west will produce a smaller poleward transport at a high latitude than it would at some position nearer the equator. This is an important feature of convergence in the region of northeast trades, as discussed by Montgomery (1936). Weenink and Groen (1952) have stated that friction may be neglected in computing currents outside latitude ". . . 2 or 3 degrees . . .". Thus convergence of the type described by Montgomery may be significant as near to the equator as 2 or 3 degrees latitude.

Neumann (1947), basing his argument on the concept of the wind drift current, has pointed out that convergence should occur along the northern edge of the belt of southeast tradewinds where the wind speed drops off toward the doldrums region.

Ekman's model cannot approximate conditions near the equator where the deflecting force is negligibly small; for the ensuing discussion, therefore, the equatorward limit of application of this model will be set at the 3° parallels in accordance with the work of Weenink and Groen. If the frictional force that acts to retard the current is incorporated into Ekman's wind drift concept, it is possible to discuss a model circulation that is meaningful in a low latitude. Since the magnitude of the retarding frictional force, and hence the magnitude of this current transport, is uncertain, the discussion will be limited to a few qualitative remarks.

Fig. 6 illustrates the steady-state transports that will occur near the equator and away from the effect of boundaries, if only the frictional and deflecting forces are considered. The transport magnitude is drawn constant. In addition to vectors representing the transport that occurs with each wind direction, the meridional components are included in Fig. 6 to emphasize the regions of convergence and divergence. For example, if the wind is steady and uniform from the east, the current in a band along the equator will be meridionally divergent. Immediately at the equator, where there is no deflecting force and since we are assuming no pressure gradient, the transport of the current is in the direction of the wind. Poleward of 3°, Ekman's wind drift model applies and the steady-state transport is at right angles to the wind in both hemispheres, directed away from the equator. Between the equator and 3° there is a gradual change of direction of the current transport. The flow is strongly divergent. Thus, with a steady east wind along the equator, and under the special conditions described, there is a divergent current.

During a wind from the west, the steady-state transport of the wind drift current outside the region between the 3° parallels is directed toward the equator. The flow is strongly convergent. If the wind blows from the south, these same considerations lead to parallel zones of divergent flow (south of the equator) and convergent flow (north of the equator). There is a transport of water across the equator toward the north. During a wind from the north the divergent and convergent zones are interchanged and the transport at the equator is toward the south.

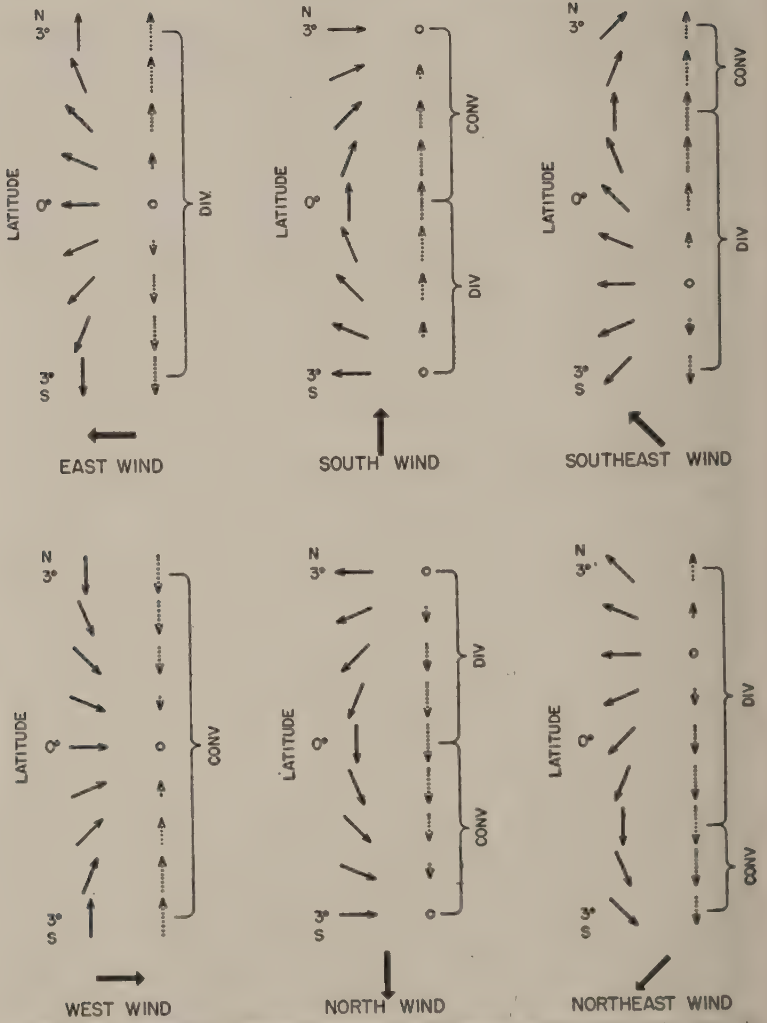

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Figure 6. Directions of current transport (solid arrows) which would exist near the equator under various wind conditions if there were no pressure-gradient force acting. The current magnitude is drawn everywhere constant (solid arrows). For each wind condition the meridional components of the current transport (dotted arrows) are drawn to emphasize the regions of meridional divergence (Div.) and convergence (Conv.).

Southeast trades blow over a large part of the equatorial Pacific throughout the year. Under conditions of the model during a southeast wind, there is convergence in a narrow band near 2–3° N, with divergence to the south as indicated in Fig. 6.

Since the pressure gradient has not been considered in the discussion leading to the divergence and convergence features of Fig. 6, it should be expected that these features will never be found exactly as described in the real ocean. In the real ocean, which is bounded and over which the prevailing wind velocity varies in space, a pressure-gradient force develops when the wind has blown for a sufficient length of time. Apparently this pressure-gradient force reduces the angle between wind direction and current-transport direction to less than a right angle. For example, the current transport chart of the North Pacific (Sverdrup, et al., 1942; 727, fig. 205) shows that there is rather close agreement in transport directions with directions shown on charts of predominant winds. Thus, it seems that the actual transport of the current usually is not directed a full right angle from the wind direction.

Nevertheless, vertical motion can occur even though the extreme divergence and convergence associated with the steady-state situations diagramed in Fig. 6 are never reached. Thus upward flow can be induced by divergence resulting from only a slight turning of the current *cum sole* from the wind direction. Similarly, convergence and divergence zones will exist as drawn for north and south winds if the current deviates only slightly from the wind direction. However, the convergence indicated during a southeast wind depends on the existence of a current directed north at some latitude, north of which the meridional component of the current decreases because of a further turning of the total current *cum sole*. Since the pressure-gradient force generally reduces the angle between current transport and wind direction to considerably less than a right angle, the convergence which appears in Fig. 6 for a southeast wind will probably not be found in the real ocean.

The divergence feature of the model in Fig. 6 seems to explain the upwelling which is apparent near the equator. The convergence feature is probably of importance in the real ocean when a wind is from the west or when the "southeast" trades back nearly to south. However, convergence north of the equator is expected during southeast tradewinds due to the deceleration of wind speed which occurs near the doldrums and due to the convergence of the wind drift current.

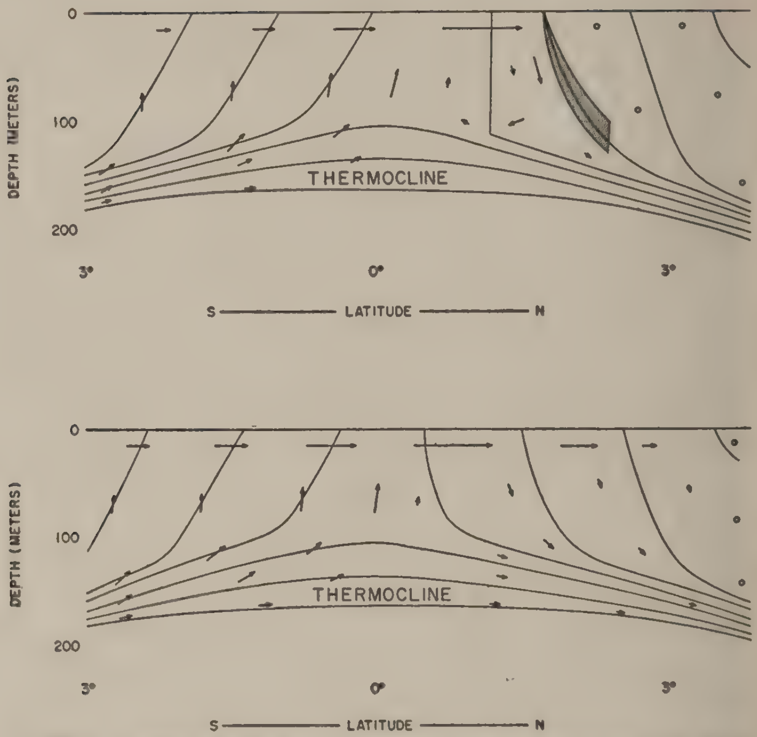

Figure 7. Schematic representation of circulation in the meridional plane near the equator during a southeast wind when front is present (*above*) and when no front is present (*below*). Full lines indicate surfaces of constant σ_t. The arrows have the character of streamlines and do not represent trajectories. The arrow shaft lengths indicate roughly the relative magnitudes of flow. Small circles indicate regions of slight and variable flow in this plane.

THE MERIDIONAL CIRCULATION

Fig. 7 presents schematically the meridional circulation which appears to prevail during a steady southeast wind. The full lines represent constant σ_t and are intended to be stationary in the two parts of the figure. The arrows have the character of streamlines and do not indicate trajectories. There are, of course, strong zonal currents.

The surface water moves with a component northward under the influence of southeast trades. Horizontal divergence near the equator induces upwelling. The current near the surface can cross σ_t surfaces toward greater density by virtue of an increase in the current's density due to admixture of relatively dense water from below; this latter feature is indicated in the figure by arrows at mid-depth, shown crossing σ_t surfaces toward lower density.

The surface water of greatest density occurs at the equator. Here the water is cooler than that which would be in radiative equilibrium with incoming solar radiation that tends to increase temperature (and decrease density) at this latitude. Therefore, as the water moves northward its density is reduced by warming and it crosses σ_t surfaces toward lower density. Horizontal convergence occurs north of the equator during southeast tradewinds. Continuity is maintained partly by sinking along σ_t surfaces.

On some occasions the northward current is blocked by an Equatorial Front, shown as a shaded zone in the upper diagram of Fig. 7. On such occasions some of the water in the lower part of the surface layer returns equatorward. In a region of persistent northeast winds across the equator, one would expect a meridional circulation similar to that appearing in Fig. 7, mirrored in the equatorial plane.

INFLUENCE OF CIRCULATION ON ZOOPLANKTON DISTRIBUTION

Graham (1941), using Carnegie data, has shown a high plankton population near the equator which he attributes to upwelling. Our results are in good agreement with this idea (King and Demond, MS). The plant and animal life that is dependent on the meridional circulation just described should exhibit certain additional features in its distribution.

Following the introduction of nutrients into the euphotic zone, e. g., by upwelling near the equator, phytoplankton and then zooplankton would be expected to increase. If the current near the equator has a northward component, as during southeast tradewinds, the plankton will be displaced northward. In general the maximum zooplankton concentration would be expected somewhere between the region of nutrient enrichment and the zone of horizontal convergence, the magnitude of the displacement northward being dependent on the time rate of zooplankton increase relative to the rate of flow northward. If this flow is relatively rapid the zooplankton may be carried to the zone of horizontal convergence north of the equator or, if a front exists, to the convergent zone south of the front. Due to its ability of directed vertical swimming, the motile zooplankton can maintain its level against the slight downward flow associated with horizontal convergence and will tend to concentrate in the convergent zone.

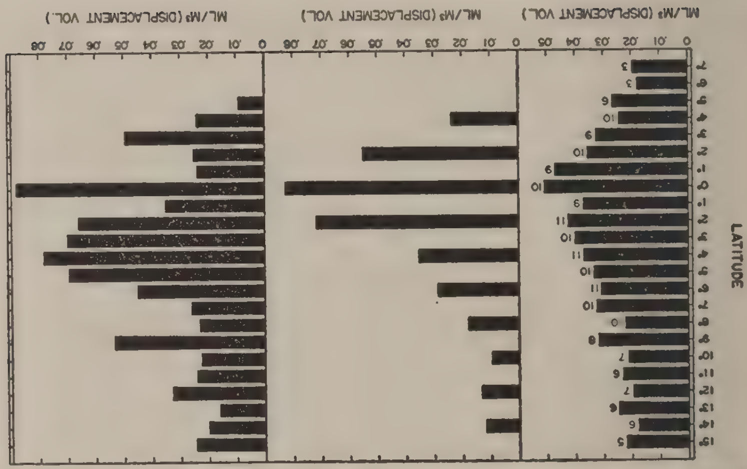

Figure 8. LEFT: Zooplankton data from 11 crossings of the equatorial currents between the 140° W and 180th meridians, combined grossly without regard for longitude or season. The number of observations included in the averaging for each degree of latitude appear at the right. MIDDLE AND RIGHT: Zooplankton data concurrent with the hydrographic sections of Figs. 2 and 3, respectively.

King and Demond (MS) have reported zooplankton results from the central Pacific. The left histogram of Fig. 8 showing the meridional variation in zooplankton abundance is based on data collected during 11 crossings of the equator between 140° W and the 180th meridian, a region over which southeast tradewinds predominate. All of these samples were taken with oblique hauls down to 200 m with nets having a body of 30XXX grit gauze and cod end of 56XXX grit gauze. The diagram includes data collected during each season. Apparently the maximum zooplankton concentration is related to the equatorial upwelling. Although the peak abundance occurs at the equator, the bulk of the plankton is displaced a little toward the north, which is consistent with the proposed meridional circulation.

The middle and right histograms of Fig. 8 are based on net hauls made concurrently with the hydrographic stations on which Figs. 2 and 3 are based. These distributions seem to show the influence of a circulation like that shown in the upper diagram of Fig. 7. The former indicates a rather abrupt decrease in zooplankton abundance northward across the front. The latter shows the zooplankton concentrated near the front.

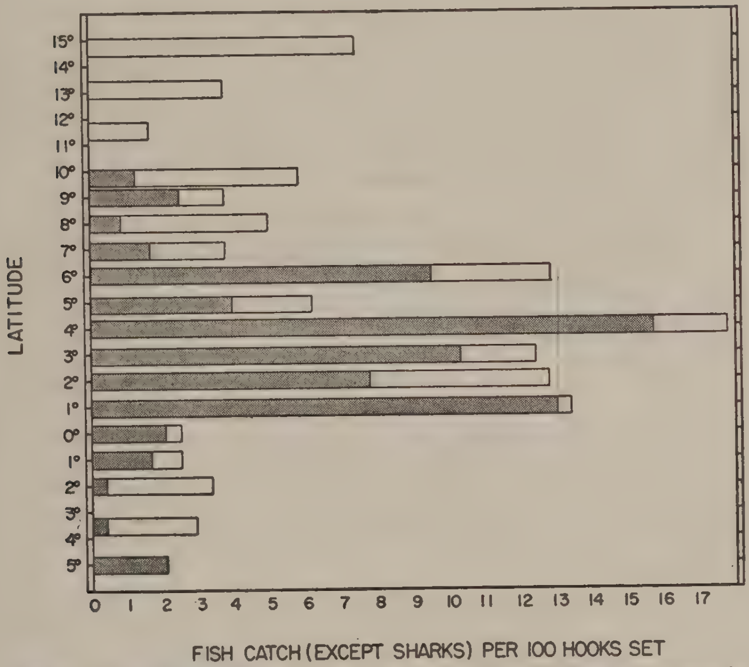

Figure 9. Abundance of large fish (except sharks) along 150° W Long. as indicated by catching rate during Smith cruise 11 across the equatorial currents. Shaded portion represents proportion of catching rate due to yellowfin tuna (*Neothunnus macropterus*) alone.

RELATED FISH DISTRIBUTION

An integral part of our program has been to relate the circulation to the distribution of large fishes. Systematic sampling of these fishes, principally of tunas, has been described in detail by Murphy and Shomura (MS).

The results of a series of fishing stations along 150° W during August–October 1951 are shown in Fig. 9. Although complete hydrographic observations could not be taken during the fishing, the thermograph records show that there was no significant front. The circulation was probably that which arises with southeast tradewinds which, according to the pilot charts, predominate near the equator during these months.

The striking abundance of large fish, particularly of yellowfin tuna (*Neothunnus macropterus*), north of the upwelling suggests a causal relationship to the circulation described in this paper. However, subsequent cruises have shown that the fish distribution sometimes is less clearly related to the circulation. Of course the fish distribution depends on a complex of factors, many of which are not considered here. Generally, however, in that part of the central Pacific over which southeast tradewinds blow, the greatest catches occur north of the equator in the region of convergence.

SUMMARY

1. Two sets of meridional sections showing the distributions of density (σ_t), salinity, inorganic phosphate, and dissolved oxygen across the equatorial currents of the central Pacific have been presented and are discussed briefly.

2. The sections show clearly the well known equatorial upwelling, but they do not support the thesis that upwelling is occurring at the northern boundary of the Equatorial Countercurrent.

3. An Equatorial Front, separating dense upwelled water near the equator from water of lesser density found generally in the surface layer of the South Equatorial Current, is described. Horizontal convergence and sinking are apparently associated with this front. The front does not coincide with the boundary of the Equatorial Countercurrent.

4. Reasons have been advanced for the existence of convergence north of the equator during southeast tradewinds when no front exists.

5. By modifying Ekman's theory of the "wind drift current" to include the total effect of friction, it is possible to discuss qualitatively a model that applies at and near the equator. In terms of this model it has been shown that there is a zone of horizontal divergence and an adjacent zone of convergence near the equator. The boundary between meridionally convergent and divergent flows shifts latitudinally and is dependent upon the wind direction. The divergence feature of this model seems to explain the equatorial upwelling. The convergence may at times produce significant sinking.

6. The circulation in a meridional plane across the equator during southeast tradewinds is summarized in Fig. 7.

7. The distribution of zooplankton and tunas in the central Pacific suggests a strong influence by the meridional circulation described.

ACKNOWLEDGMENT

I sincerely appreciate my association with Dr. R. B. Montgomery of Brown University, under whose guidance I worked on parts of this paper. Messrs. O. E. Sette, T. S. Austin, G. I. Murphy, and E. D.

Stroup read the manuscript and made a number of helpful suggestions. Mr. R. V. Mead and Mrs. M. L. Godfrey gave invaluable assistance in carrying out the processing of the data. I wish to thank the captain and crew of the HUGH M. SMITH who spent months at sea collecting the data on which this paper is based.

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Equatorial Undercurrent in Pacific Ocean Revealed by New Methods

Townsend Cromwell, R. B. Montgomery,[1]
and E. D. Stroup

Pacific Oceanic Fishery Investigations,
U.S. Fish and Wildlife Service, Honolulu;
Brown University, Providence, R.I.;
and *Pacific Oceanic Fishery Investigations,*
U.S. Fish and Wildlife Service, Honolulu

Indications of an eastward current at the equator beneath the westward South Equatorial Current came originally from the drift of long-line fishing gear in use from vessels of the Pacific Oceanic Fishery Investigations of the U.S. Fish and Wildlife Service. Direct observation of drifting objects, or "drags," from the Service's research vessel *Hugh M. Smith* during Aug. 1952 proved the existence of this eastward current in the central Pacific near the equator in the lower part of the surface layer and upper thermocline.

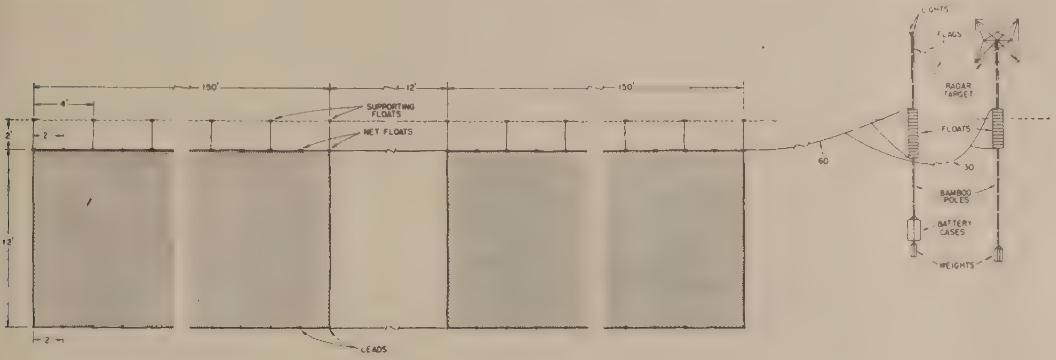

Fig. 1. Drag used to measure the surface current.

The surface current at three stations was observed by following a surface drag continuously for several days and determining its movement by celestial navigation. On 12 of the 18 days devoted to following the surface drag, deep drags with identifying surface floats were released. The velocity of the deep drag was measured relative to the motion of the surface drag by following the identifying float with the vessel and tracking the surface drag by radar up to ranges of 5 mi. Vector subtraction then gives the deep drag's true velocity, which can be used to make a close estimate of the velocity of the deep current.

The surface drag (Fig. 1) consisted of two 150 by 12-ft panels of fine-mesh netting joined end to end and buoyed to locate the top of the mesh 2 ft below the sea surface. The use of netting combined large resistance with ease of handling and stowage. A pole carrying a radar target and one carrying a flag and light were attached to the downwind end of the nets.

The deep drags (Fig. 2) were similar to a common form of sea anchor. Each consisted of a light muslin cone attached to an aluminum alloy hoop weighted at the bottom and buoyed at the top so that it would remain upright. Piano wire of diameter 0.72 mm joined the deep drag unit to two streamlined floats, one at the sea surface and the other slightly submerged. The drags used were 3 and 4 m in hoop diameter, so large that retrieval was impossible and a drag could be used only once.

Wind resistance of the poles prevented perfectly free movement of the surface drag with the current, and water resistance of the wire and floats similarly affected the deep drags. Corrections to reduce the drag velocities to current velocities are being determined, and a complete account of the data and results is being prepared for later publication. However, the submerged countercurrent can be described now in terms that will not be altered by these corrections.

The 12 observations of the deep current were made near 150°W from 2°54′S to 7°05′N. The first, at 2°54′S at a depth of 200 ft, gave a northwesterly current of a little less than half a knot.

The following eight observations were in almost daily succession during the second drag station. The first four of these from 0°14′N to 1°31′N at depths in the lower part of the surface layer and upper thermocline indicated currents with easterly components. At the first of them, at 0°14′N, the surface current was nearly 1 knot north, while the deep drag indicated an east current stronger than 1 knot. The last four observations on this station, from 1°50′N to 2°43′N, revealed zonal flow directed west.

The final three drags were used at the third drag station, near 7°N in the Equatorial Countercurrent, where the current was easterly by both surface and deep drags.

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[1] Research sponsored by Office of Naval Research.

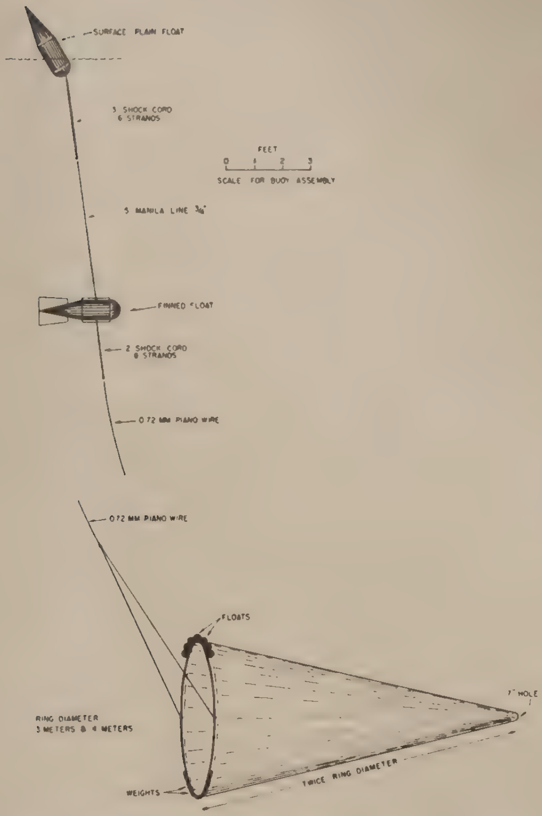
SURFACE PLAIN FLOAT
3 SHOCK CORD 6 STRANDS
FEET
0 1 2 3
SCALE FOR BUOY ASSEMBLY
3 MANILA LINE 3/16"
FINNED FLOAT
2 SHOCK CORD 6 STRANDS
0.72 MM PIANO WIRE
0.72 MM PIANO WIRE
FLOATS
7" HOLE
RING DIAMETER
3 METERS & 4 METERS
TWICE RING DIAMETER
WEIGHTS

Fig. 2. Deep drag and buoy assembly used to measure the deep current.

The submerged east current was, thus, observed in a narrow zone near the equator, the speed of the axis exceeding 1 knot. It was separated from the Equatorial Countercurrent by water with a westward velocity component.

As mentioned in the opening paragraph, observations of the drift of long-line fishing gear have indicated the presence of the submerged current. The long line is a system of cotton lines suspended from buoys and floated freely in the water, the main mass of line lying, in these trials, in the lower part of the surface layer. This gear has been set very near the equator a number of times on various longitudes and, on several occasions, has moved eastward in spite of opposing southeast trade winds and seas at the surface, suggesting that the submerged current is prevalent near the equator in the central Pacific. Whether or not the current prevails in the eastern and western Pacific and in the Atlantic remains to be determined by further study.

In part, the dynamics of the current seem clear. The surface layer of warm water deepens westward, so that throughout this layer there is an eastward component of pressure-gradient force (*1*). Below the depth of influence of the southeast trade winds, water flows east in response to the pressure gradient. These considerations do not explain the narrowness of the current.

On this basis, the countercurrent at the equator can be expected to extend up to the sea surface when the wind stress is released or sufficiently diminished. Such an occurrence could explain reports of eastward drift of vessels close to the equator in the eastern Pacific and the Atlantic (*2*).

The countercurrent at the equator may, thus, occasionally be observed at the surface but is apparently more prevalent in the lower part of the surface layer and in the thermocline. For this reason the name "Equatorial Undercurrent" is proposed.

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Received March 8, 1954.

Reprinted from SCIENCE, July 2, 1954, Vol. 120, No. 3105, pages 36–38.

A Fungus Disease in Clam and Oyster Larvae

H. C. Davis, V. L. Loosanoff, W. H. Weston, and C. Martin

U.S. Fish and Wildlife Service, Milford, Connecticut, and The Biological Laboratories, Harvard University, Cambridge, Massachusetts

The improved method for growing lamellibranch larvae developed at the U.S. Fish and Wildlife Service laboratory, Milford, Conn., has offered many new possibilities and approaches for studying the behavior and physiological and ecological requirements of these organisms (*1, 2*). Using this method, the larvae of more than 15 species have been successfully cultured through metamorphosis at our laboratory. Of these, however, the larvae of the common clam, *Venus mercenaria,* and of the American oyster, *Crassostrea virginica,* have been most widely studied (*3, 4*).

Clam larvae are especially suitable for experimental work, and usually their cultures are carried through metamorphosis without experiencing undue difficulties. On several occasions, however, some cultures of an experimental series would show a heavy mortality unrelated to the experimental treatment. Recently, while examining such a culture of clam larvae, Davis noticed an organism, which was tentatively identified as a fungus, in many of the dying and dead larvae. Loosanoff and Davis later observed the same or a related fungus in larvae of *C. virginica, Venus mortoni,* and the hybrids of *V. mortoni* ♀ crossed with *V. mercenaria* ♂ and *V. mercenaria* ♀ *crossed* with *V. mortoni* ♂.

The presence of fungus in our larval cultures appears to be of endemic nature. Usually there are only a few infected larvae in many of the cultures, yet only in rare instances does the disease acquire epidemic proportions, involving the majority of the larvae, and within 2 to 4 days killing almost the entire population.

During the outbreak of the epidemic, many larvae may be observed in various stages of disintegration, with the fungus quite apparent in their interior. Usually several species of flagellates and ciliates invade the dead or dying larvae to feed upon their tissues, leaving, within a short time, empty shells with practically no traces of the fungus. Even in the cultures in which mortality is especially severe, there usually are some larvae that live through the epidemic without contracting the disease, which suggests the possibility that they may be immune to the fungus.

The fungus is transmitted by zoospores which emerge through the tip of the exit tube that the sporangium puts forth to the exterior of the infected larva. The zoospores are released in an intermittent stream from these openings, and for a short time they are seen swarming near the edges of the shells of the larvae from which they were released but soon disperse through the water. Theoretically, densely crowded larval cultures should present a better opportunity for development of fungus epidemics than field conditions, because of the proximity of the larvae to one another and, hence, the difficulty of their escaping infection by the large numbers of zoospores swarming about in the water.

Larvae of all ages, from the very early free-swimming stage to those ready to metamorphose, have been seen parasitized by the fungus. Individuals that had already metamorphosed into juvenile clams have also been found heavily infested on several occasions, and release of zoospores from the fungus in such animals was observed.

At present we do not know the optimum temperature or salinity for the growth of the fungus or the limits it can withstand. Thus far, the larval cultures in which the fungus infection was noticed have been kept within a temperature range of 19.0 to 27.0°C and in a salinity of about 27.0 parts per thousand. Nor do we know whether some infected larvae may survive the infection, recover from it, and later proceed with normal development. It seems, however, that the majority of the larvae stop growing and die soon after they become infected.

Even in this preliminary phase of our investigations, we find that the nature and development of the fungi responsible for this destructive disease show certain distinctive and significant features. Within the larvae, the fungus develops as a contorted, looped, and sparsely branched thallus of torulose character with constrictions at intervals between the swollen and often lobed segments. In both oyster and clam larvae, the thallus may be limited in extent, occupying a relatively small part of the shell cavity, so that its form and structure can be readily seen (Fig. 1*A, B, C*). In contrast, in many of the specimens of invaded clam larvae examined, there is much more extensive growth, the fungus occupying a large proportion of the shell cavity with its lobes or segments so densely crowded together in a radiate arrangement that the details of thallus organization cannot be discerned with certainty (Fig. 1*D*). It has not yet been determined whether this difference in thallus character indicates that the simpler, less extensive growth represents a younger phase which will later develop into the more elaborate one or signifies that two different species of fungi are concerned.

As the fungus rapidly develops, the segments mature into sporangia, each with an exit tube extending to the exterior, as can be seen in Fig. 1*D*. The zoospores, already fully developed, emerge through these tubes into the surrounding water. In some larvae, the tubes may protrude considerable distances from the larval shells (Fig. 1*E*).

No sexual stage of the fungus or any resting spores or other resistant entities have been seen in any of the many specimens examined.

Although the identity of the fungi concerned has not yet been specifically determined, their taxonomic affiliations are sufficiently clear to permit tentative designation. Since their thalli are simple in organization with limited extent of development, since their walls show a weak but conclusive cellulose reaction to chloroiodide of zinc, and since their zoospores are biflagellate, it is clear that these fungi belong among

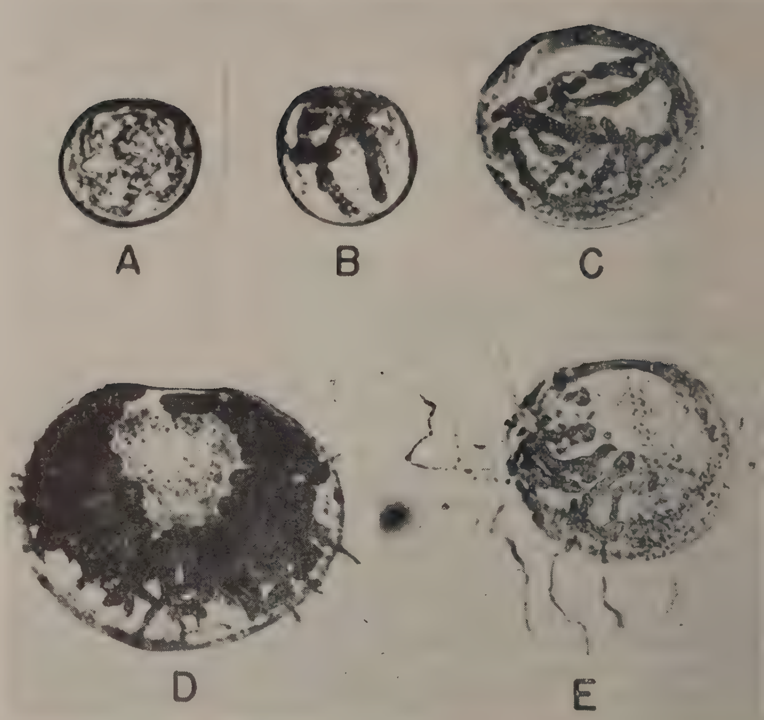

Fig. 1. Larvae infested with fungus. *A* and *B*, young oyster larvae; *C*, young clam larva; *D*, old clam larva; *E*, young clam larva. Larvae *A*, *B*, *C*, and *E* are stained with neutral red, larva *D*, with cotton blue (× 224).

the lower members of the biflagellate series of the Phycomycetes. For generic affiliation within this series, the genus *Lagenidium* at once suggests itself both because the looped, contorted, and torulose nature of the thallus is similar and because one species, *Lagenidium calinectes*, is known to occur in salt water and to cause similar destructive epidemics among the larvae of the blue crab in Chesapeake Bay (*5*). In contrast to *Lagenidium*, however, the zoospores in the fungi of our clam and oyster larvae are already fully developed when they emerge from the sporangium through the exit tube and are ready to swim away.

All the critical distinctive features of these fungi affiliate them most closely with the genus *Sirolpidium* of the family Sirolpidiaceae. Yet the two species of *Sirolpidium* thus far recognized, although both are marine and parasitic, have been reported only on such algae as Bryopsis and Ceramium and have never been found on animal hosts. Therefore, the indications are that the fungi attacking the larvae of clams and oysters probably represent one or perhaps even two new species.

It was shown by Loosanoff that the fungus acquires a deeper stain than larval tissues if living larvae are kept in a solution of neutral red in sea water. Thus, this stain can aid in detecting the first appearance of the fungus, and also, by "tagging" the infected larvae, we can study the progress of the epidemics, the percentage of survival of fungus-affected individuals, and other pertinent features. Neutral red may also prove valuable in staining mass samples of natural plankton for easier examination and for determining whether some of the organisms constituting it are infested with the fungus. The usual cotton blue lactophenol technique can also be used to demonstrate presence of the fungus in preserved samples.

In experiments at the U.S. Fish and Wildlife Service laboratory at Milford, we are attempting to find which additional species of lamellibranch larvae may become infected with the fungus disease. At the same time, we are carefully examining the internal condition of the larvae found in our field plankton samples to ascertain whether the fungus occurs under natural conditions.

We believe that this is the first report of a fungus parasite in lamellibranch larvae. Since only a few cases of the occurrence of parasitic fungi in marine animals are known, this discovery should be of considerable biological interest. The possibility exists that the occurrence of an epidemic of this fungus among lamellibranch larvae in nature may seriously affect the sequence of events in the food chain. It is also possible that if we develop a method for control of the fungus under hatchery conditions, a problem on which we are working at present, the artificial cultivation of clams, *Venus mercenaria*, and other mollusks may be rendered commercially feasible.

We wish to express our thanks to our colleague, C. A. Nomejko, for preparation of the photograph that accompanies this article.

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1 March 1954.

Calving of the California Grays

Raymond M. Gilmore & Gifford Ewing

THINGS we are sure of that turn out to be happily untrue add spice to the life of a scientist. We have recently had the fun of uncovering a fallacy in the well-publicized natural history of the California gray whale.

During the past century the annual parade of these enormous mammals, along the coast and past the headlands of southern California, has excited the interest and curiosity of casual shore watchers and conservationists alike. Indeed, before the days of the '49ers it was the gray whale that brought ships from New England around the Horn to the coast of California.

The animal has twice survived near extinction at the hands of whalers but has recovered each time, and now is annually seen in large numbers swimming close to shore, seeking shelter in lagoons and bays, in a migration that terminates in the desolate inland waterways of the Baja California desert. It is in these quiet waters, sometimes 20 or 30 miles from the open sea, that the cows give birth to their 12-foot calves and it is in these waters that the annual remating takes place.

After much patient study it had generally been agreed that the breeding range of the species was limited to a half dozen locations along the middle one-third of the Pacific coast of the peninsula and it was believed that the maximum population which could be supported was that which would fully exploit the restricted nurseries in this area. Although occasional stragglers were reported from other areas, little thought was given to the possible discovery of additional calving grounds, and the limits of the known breeding range have not been significantly extended since the mid-1800's.

Recently, however, we have had the good luck to find gray whales calving in small numbers in two entirely new locations on the eastern side of the Gulf of California along the coast of Sonora and Sinaloa, some 350 miles beyond the most southerly heretofore recorded nursery.

Seven years of study begun by Dr. Carl L. Hubbs of the Scripps Institution of Oceanography and pursued by him and by many coöperating scientists including ourselves, have involved ships, skiffs, dug-outs, aircraft and helicopters, as well as the examination of historic records and interviews with local fishermen. Insofar as these studies defined the breeding range of the gray whale, they may be summarized as follows:

San Diego and probably adjacent *Mission Bay* – once heavily populated, but now no longer entered, probably on account of the heavy boat traffic. In an earlier day the ladies of San Diego dared not be rowed across the bay to their favorite picnic site on North Island, because of the prevalence of gray whales spouting in the harbor.

Bahía de Todos Santos, with its Mexican city of Ensenada–now visited by occasional stragglers which do not stay to calve.

Bahía San Quintín – the situation is similar to that at Bahía de Todos Santos.

Bahía de Sebastian Vizcaíno–heaviest concentration of whales during the breeding season. From the southeast margin of this bay, *Laguna Scammon* and *Laguna Guerrero Negro* (Black Warrior) extend deeply into the Vizcaíno Desert, and these lagoons are now the largest and most important calving nurseries.

Bahía Ballenas – extends into *Laguna de San Ignacio* which also is heavily populated.

Estero – just north of Bahía Magdalena; three entrances, *Boca Las Animas* at the north end, *Boca Santo Domingo* in the middle and *Boca Soledad* at the south; well populated, especially south of Boca Soledad.

Bahía de la Magdalena – a huge bay, perhaps once the most important of the calving and mating areas of the gray whale, now thinly populated, probably because of the rather heavy fishing traffic.

Bahía de Almejas–just south of and connected with Bahia Magdalena; well populated. Until recently this was thought to be the southernmost nursery.

This sums up the known winter range of the California gray whale. So far as the writers are aware, none of the lagoons north of Mission Bay have ever been frequented by calving grays within historic times, despite the apparent suitability of such protected bodies of water as Newport Bay, Anaheim Bay, San Pedro Bay, Morro Bay and especially San Francisco, Bolinas, Tomales and Humboldt bays.

To be sure, apparent stragglers have been reported from time to time in odd places, as for example the three cows with small calves which Hubbs saw on the northwest side of Isla Guadalupe on February 3, 1950. The small size of the calves makes it probable they had been born here some 250 miles offshore from their nearest known regular nursery in Scammon Lagoon.

Nevertheless, as our studies progressed from year to year certain facts began to emerge which caused us to wonder whether there might not be at least one other nursery not known to us. For one thing Charles Scammon,* the famous whaler and chronicler of the gray whale, had written somewhat ambiguously that the gray whale never extended its migration south of 20° north latitude, but he nowhere stated categorically that whales were found this far south, nor said whether they were seen along the coast or far out at sea. We presumed he referred to accidental encounters, else more would have been known of these southern migrators. Nevertheless, such a southern limit was 3° or approximately 180 nautical miles south of the tip of Baja California, opposite Cabo Corrientes in the Mexican state of Jalisco.

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*[*] *The marine mammals of the north-western coast of North America,* San Francisco and New York. 1874. 319 pp., 37 pls. (page 22).

Reprint from PACIFIC DISCOVERY (Vol. VII, No. 3, May-June, 1954, pages 13-15), a bi-monthly publication of the California Academy of Sciences, San Francisco.

While we flew in a small land plane twice in early 1953 for long hours along the desolate, sunbaked, uninhabited and rugged coast line of Baja California, Ewing was happily engrossed in piloting the plane, while Gilmore had time to contemplate Scammon's cryptic remark. The annual census taken by Hubbs had shown that the population was definitely increasing as a result of the complete protection from hunting provided by the International Whaling Convention of 1937, and the successive annual flying census had shown a steady southward push of the population with an increasing number of stragglers scattered along the coast as far south as Cape San Lucas.

On February 3, 1953, Ewing and Andreas Rechnitzer saw a cow and calf just within the Cape near San Jose del Cabo; and along the Pacific Coast between the Cape and Bahía de Almejas they counted 78 gray whales, including two calves. On February 27, 1953, Ewing and Gilmore again saw a cow and calf near San Jose. We wondered what so large a number of gray whales were doing so far south of the southernmost established nursery at Almejas.

Was this the restless wandering of the adolescents and other nonbreeders or were these adults probing for new calving grounds, or perhaps returning from nurseries not yet known? Three times Ewing and Hubbs, Ewing and Rechnitzer, and Ewing and Gilmore reconnoitered the east coast of the peninsula, with negative results. The whales did not seem ever to enter the Gulf proper. The small number of calves among those seen south of Almejas, and the well established restriction of the calving grounds to points much farther north, prompted Gilmore to conclude that these southern individuals were indeed stragglers, aimlessly passing the time before the northward migration began. Nevertheless the air map showed many coastal lagoons and bays on the eastern side of the Gulf, along the coast of Sonora and Sinaloa, the configuration of which aroused our curiosity and kindled our resolve to explore them during the winter of 1953-1954.

Our break came in early January, 1954, during the course of a flight made along the eastern shore of the Gulf by Ewing in company with Dr. Robert Menzies, a staff member at the Scripps Institution of Oceanography, the object of which was the collection of marine isopods and a study of the distribution of the common marine borer Limnoria.

While Menzies was busy hacking in wood structures for Limnoria, Ewing stayed with the float plane which, because of its unfamiliarity, attracted large crowds from the isolated fishing villages along the way. With his very limited Spanish Ewing asked the local fishermen about whales, but got only one bite. In a lagoon, midway between Mazatlán and Topolobampo, one village patriarch remembered seeing whales and calves in years gone by. He thought perhaps they still came in to Bahía de la Reforma, the next lagoon to the north. He told of mothers that spent the winter with their calves, arriving in early February and leaving in April, and of how these mothers would place themselves between their babies and the vicious *bufeos* (killer whales). He could not say whether these whales were similar to the ones found in Baja California *because he had never been on that side of the Gulf.* Shortage of gasoline kept Ewing and Menzies from a systematic search of Bahía de la Reforma, but during a single pass over the bay Menzies spotted one lone whale that seemed to share our astonishment at the encounter, for it stuck its head straight up out of the water in a "spy-hop" typical of the gray whale.

Shortly thereafter, in early February, Gilmore and Ewing made a similar flight in the same plane expressly to look for gray whales and land on the water in all likely lagoons and bays to query fishermen about the whales and any pertinent past history which might throw light on the quest.

Much to our surprise and pleasure we actually saw and counted 44 gray whales, of which 26 were adults and 18 calves, meaning that at least 18 of the adults were cows. They were found in the following places:

		Adult	*Calf*
1 Feb.:	Punta Final, northwest side of Gulf, just north of Bahía de Los Angeles. Probably a stray adult	1	
3 Feb.:	Bay off Puerto Yavaros, just north of Topolobampo, 26° 40′ N.	7	6
3 Feb.:	Bahía de la Reforma (B. Santa Maria, just south of Topolobampo), near south entrance (not included in final count because this bay was revisited on northern flight and more were counted), 25° N.	(4)	(2)
5 Feb.:	Bahía de la Reforma, on return flight, near south entrance	5	2
	Bahía de la Reforma, near north entrance in channel	13	10
		26	18

In the north channel of Bahía de la Reforma another pair was listed as doubtful. And just north of Bahía Banderas, far to the south between San Blas and Puer-

California gray whale "spy-hopping."
(U. S. Fish & Wildlife Service)

to Vallarta, near 20° N., we saw another whale which might have been a gray, making a possible 47. We flew too fast to have scored the same whale twice, but on the other hand we may have missed some submerged.

The flight covered the Gulf coast from Punta Diggs near San Felipe to Bahía de Los Angeles in the northwest Gulf; thence across the Gulf past the southern end of Isla Angel de la Guarda and Isla Tiburon, to Bahía Kino (landing in the open water near the village), and to Guaymas. The next day we flew to Mazatlán, with stops at the estuary of Río Yaqui, at Estero de la Luna at Punta Lobos, Bahía Huivuilay (Pabellon Colorado), at Puerto Yavaros, at Laguna de Agiobampo (Bucarehius), and Topolobampo. The flight from there, after refueling, was straight to Mazatlán, with orbits over Laguna or Bahía de Navachiste and Bahía de la Reforma (or Santa Maria).

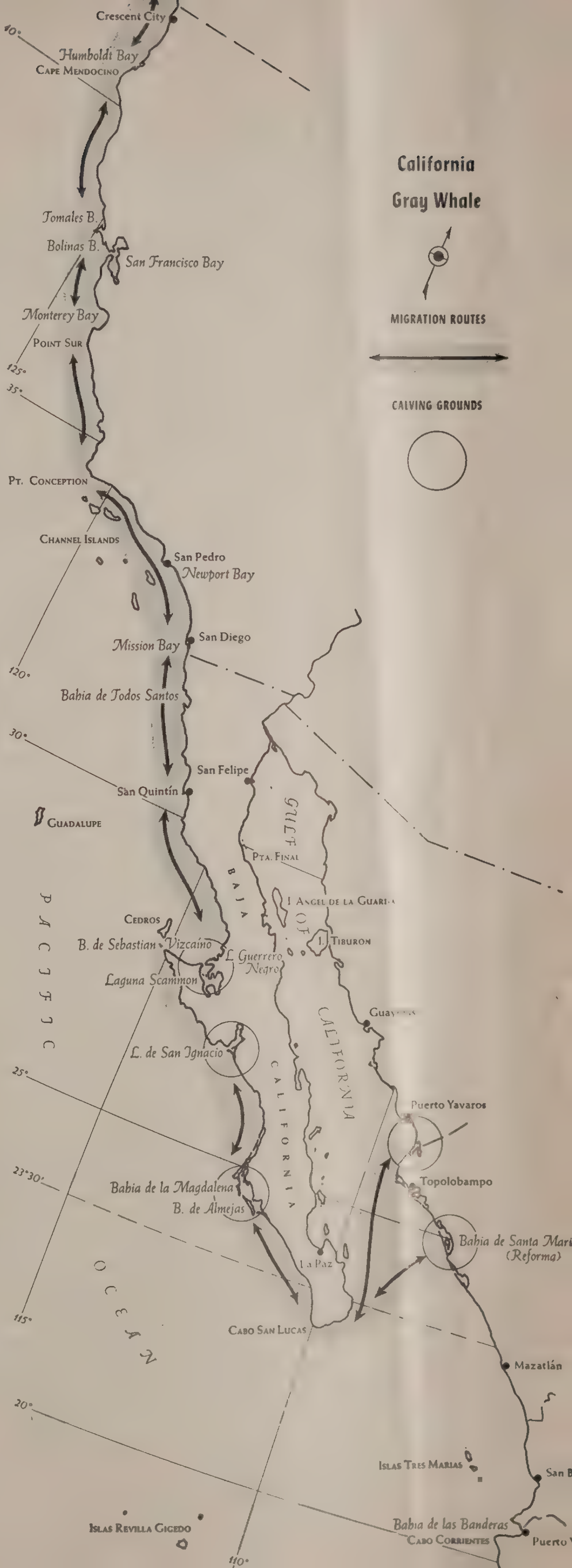
From Mazatlán we made a "round robin" flight to Puerto Vallarta and return, with intermediate stops at San Blas and Isla Santa Isabella to inquire for whales. Coming north from Mazatlán again, before crossing the Gulf to La Paz, we scrutinized Bahía de la Reforma thoroughly along its inside channel near the north and south entrances and outside the island-bar. We saw many more gray whales than on our way south, leading us to replace the count of 3 February with that of 5 February.

Nowhere we stopped and inquired did we learn of whales concentrating in winter in the lagoons or adjacent waters outside, though humpbacks were found common at Isla Isabella just off San Blas, where they were seen apparently mating and feeding.

On a flight over the same area with Ewing on 17-18 February in a Cessna 180, Dr. Hubbs and Mrs. Laura C. Hubbs saw almost the identical number of gray whales in exactly the same places as on the flight by Ewing and Gilmore. This points to well-established residence of the same cows in the same area for the duration of the calving season.

The significance of this discovery of calving grounds on the eastern side of the Gulf of California is that it explains survival of the gray whale during the critical years of heavy whaling from 1850 to 1880 and again from 1924 to 1938, when numbers appeared to have dropped to the vanishing point. Also, the calving grounds on the Gulf are large enough to allow significant increase of the population beyond what issues from the already well known calving lagoons of the west side of Baja California.

Two other facts of interest stand out in thinking about the gray whales in the Gulf; first, the numbers were small, and may never have been large, else the whalers should have discovered them long ago; second, most were cows with calves, indicating that mating takes place chiefly on the west coast of Baja California where intense mating activity has often been observed.


California
Gray Whale
MIGRATION ROUTES
CALVING GROUNDS
Crescent City
40°
Humboldt Bay
Cape Mendocino
Tomales B.
Bolinas B.
San Francisco Bay
Monterey Bay
Point Sur
125°
35°
Pt. Conception
Channel Islands
San Pedro
Newport Bay
Mission Bay
San Diego
120°
Bahia de Todos Santos
30°
San Felipe
San Quintín
Guadalupe
Pta. Final
GULF
BAJA
OF
CALIFORNIA
I. Angel de la Guarda
Tiburon
Cedros
B. de Sebastian Vizcaíno
L. Guerrero Negro
Laguna Scammon
Guaymas
L. de San Ignacio
PACIFIC
25°
Puerto Yavaros
Topolobampo
CALIFORNIA
23°30'
Bahia de la Magdalena
B. de Almejas
Bahia de Santa Maria (Reforma)
La Paz
OCEAN
115°
Cabo San Lucas
Mazatlán
20°
Islas Tres Marias
San Blas
Islas Revilla Gigedo
Bahia de las Banderas
Cabo Corrientes
Puerto Vallarta
110°

Map prepared for *Pacific Discovery* from data supplied by the authors.

So far we have not seen whales crossing the open Gulf between Cape San Lucas and the mainland. Possibly some gray whales spend the summer near the head of the Gulf as many finbacks do, and as some grays do at Crescent City, northern California. The lone one seen at Punta Final encourages this idea which, however, is not yet confirmed as fact — except for that one, all the whales seen so far near the head of the Gulf have been finbacks.

Thus, a new chapter has been added to the natural history of the gray whale. Many details of their life cycle remain to be uncovered, some by future flights to Mexico and some from such easy points of observation as the public whale watch maintained by the National Park Service at the Cabrillo National Monument on Point Loma, San Diego. As the full story unfolds we shall learn whether in the future a limited harvest of surplus whales may be permitted for meat and other useful products, without again decimating the population.

Reprinted from Zoologica, *Scientific Contributions of the New York Zoological Society,*
Vol. 39, Part 1, April 15, 1954

4

Certain Measures of Intergradation and Divergence

Isaac Ginsburg
U. S. Fish and Wildlife Service,
Washington, D. C.

(Text-figure 1)

TAXONOMISTS during the pioneering stages of the science generally established and described their species on the basis of one or very few specimens. To the present day some taxonomists pursue their studies according to the methods of the pioneers. Of necessity, all of us often have to follow the same course, because of the lack of adequate material. However, the information gained by a taxonomic study of one or a few specimens of a species gives a mere smattering of our knowledge of the species. It tells us very little or nothing about variability within the species, something we need to know in order to understand properly its morphology and its affinities to the species that are immediately related to it. Therefore, by and large, the trend in modern taxonomy, and rightly so, is toward extensive studies of intraspecific or intrapopulation variability, that is, the extent and manner of individual variability within the limits of the species, or population of lower rank, with regard to those characters in which natural populations diverge.

For an adequate knowledge of the relationship and differences between closely related species of the same genus, it is desirable and necessary to know the limits and manner of individual variability of their distinguishing characters. The same holds for the minor natural populations within the species. The differences or divergences between any one pair of closely related populations, for any given character, are ascertained by determining for each individual specimen within the sample studied the numerical value of the character studied. The individual data are then tabulated, and the difference between the two populations determined by comparing the evidence presented by the two sets of tabulated data.

As studies of intrapopulation variability increase in scope and extent, it becomes evident with ever-increasing forcefulness that the gap which many taxonomists, especially those of the past, thought exists between closely related species of the same genus, is often becoming ever more narrowed or obliterated altogether. The discovery is being made repeatedly that populations which have been, and should be, afforded full species status intergrade somewhat in the very characters that have been and are being used to distinguish them. Moreover, it is being discovered that divergences between pairs of closely related populations are of all degrees of magnitude and that no sharp or definite line can be drawn between the species category and that of subspecies.

Need for These Measures.—As divergences between closely related populations are of differing extents or degrees of magnitude, it becomes imperative to have some numerical measure of the degree of divergence between a pair of populations compared for a given character. This gives the taxonomist a criterion for drawing conclusions regarding the taxonomic rank to assign to the two populations which he studies and compares, namely, whether to designate them as full species or to a particular one of the several graded intraspecific categories in the hierarchy of lesser populations. In theory, the species may be conceived as the end point in, or as comprising, a graded series of lesser populations the relationship of which increases in relative remoteness, somewhat in the following order. The most intimately knit population, consisting of a group of individuals that are the offspring of the same parents, may be designated as the family (with a small "f"). Two or more closely related families may be said to constitute a clan; two or more related clans may be said to make up a tribe. Closely related tribes theoretically constitute a variety; related varieties constitute a race; related races make a subspecies. In practice, the lesser of these minor categories are virtually altogether in the realm of theory at this stage of the science. At present we need consider only three of the upper intraspecific categories, the subspecies, the race, and the variety. In actual practice, in the great majority of instances, only the subspecies is taken cognizance of by most taxonomists. Perhaps what should more properly be designated race or variety is sometimes called subspecies. Some taxonomists use the terms race and subspecies synonymously to cover the concept of the same category.

For the present it would seem desirable to bestow a formal Latin name on the subspecies only and designate the race and variety by some informal designation, preferably one that indicates the geographic region that it inhabits, such as the "Chesapeake Bay race" or the "Potomac River variety." Perhaps in fewer instances the informal name might refer to the ecological niche that it occupies. That is, it seems best to refrain from going beyond the trinomial in nomenclature.

From the viewpoint of practicality, it is desirable that any such proposed measure have certain attributes. The taxonomist is a busy man and has to deal with thousands of populations of species rank or lower. It is, therefore, important for any such measure to be quickly determinable from the tabulated data. Also, the applicability of the derived number to the problem at hand and its pertinence in drawing acceptable taxonomic conclusions must be readily comprehensible. A proposed measure may have elegance and ingenuity from the mathematician's viewpoint, but if its derivation is too time-consuming and its pertinence not plainly evident, it will not serve as a useful tool to the taxonomist.

Some time ago I proposed two measures that seem to have the desired attributes (1938). One I called the index of intergradation, the other the index of divergence. These two indices are complementary; the greater the intergradation the less the divergence, and vice versa. For any given character compared between two populations the sum of the two indices equals 100. Some supplementary phases connected with this problem were considered by me in other papers (1937, 1939 and 1940).

Judged by private conversation with taxonomists, it seems that some misapprehensions exist in regard to the two indices as I proposed them, and the following statements seem to be in order. (1) My index of divergence cannot properly be described as the percentage of identifiable specimens in the two samples compared. (2) My index of intergradation is not represented by the percentage of the actual number of intergrading specimens in the two samples.

The paper cited above, by the use of actual taxonomic data, shows how the two proposed indices are applied in practice. The present paper discusses an underlying basis for these two indices. This may be done by considering two hypothetical populations.

Procedure.—Let us assume two natural populations, alpha and beta, that differ in a number of characters the most divergent one of which, or the principal character of which, is represented by the frequency distribution given in Table I. The class numbers might represent any character, such as the number of fin rays in a fish, the number of rays in a flower, the number of segments in the antenna of an insect, the tail length in a mouse or the length of the wing in a bird, in any chosen unit.

TABLE I.

FREQUENCY DISTRIBUTION OF THE NUMERICAL VALUES OF THE PRINCIPAL CHARACTER IN TWO HYPOTHETICAL DIVERGING NATURAL POPULATIONS, ALPHA AND BETA. (The function of the heavy vertical line, the dividing line, is discussed in the text).

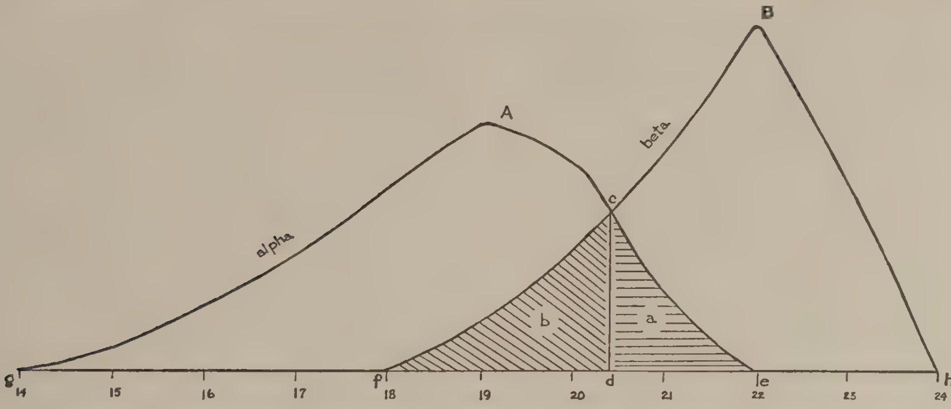
	Distribution								
Population	15	16	17	18	19	20	21	22	23
alpha	6	21	34	58	77	68	26		
beta					33	78	143	231	127

Changing the numerical frequencies in Table I to percentages of the total number of specimens in the two respective hypothetical samples, we get a distribution as given in Table II.

TABLE II.

FREQUENCY DISTRIBUTION OF THE PRINCIPAL CHARACTER IN TWO HYPOTHETICAL DIVERGING POPULATIONS, ALPHA AND BETA, BASED ON THE SAME ASSUMED DATA AS IN TABLE I, EXCEPT THAT THE FREQUENCIES ARE EXPRESSED AS PERCENTAGES OF THE TWO RESPECTIVE HYPOTHETICAL SAMPLES.

	Distribution								
Population	15	16	17	18	19	20	21	22	23
alpha	2.1	7.2	11.7	20.0	26.6	23.4	9.0		
beta					5.4	12.7	23.4	37.7	20.8



Text-fig. 1.—Diagrammatic representation of the assumed data presented in Table II of two hypothetical populations, alpha and beta. Drawn by Mildred H. Carrington.

On the basis of the percentage figures in Table II, construct two overlapping curves (or polygons or histograms), as in Text-fig. 1, the curve on the left representing alpha, that on the right beta.

It should be stated at this point that the method here discussed is generally applicable to data derived from fairly homogeneous populations and based on fairly adequate samples. The comparison of two such sets of data from two closely related populations will usually result in two curves that intersect at one point. This will apply to the great majority of instances that may be encountered in taxonomic practice. In the relatively few special instances that may be expected, in which the distributions are irregular, and the curves intersect in more than one point, some modification of this method might be necessary.

Let the area enclosed by the curve and base line representing alpha be denoted by A and that representing beta by B.

From the point of intersection of the two curves draw a vertical line *cd* to the base line.

Then, the overlapped part of the graph may be considered as consisting of two—usually unequal—parts, namely, *ced* and *cfd* that may be said to represent the parts that A and B, respectively, contribute to the overlapped area.

Let areas *ced* and *cfd* be represented by *a* and *b*, respectively, *a* being longitudinally hatched in the graph and *b* obliquely hatched.

Index of Intergradation.—Now, let a′ represent the percentage of *a* into A, and b′ represent the percentage of *b* into B. Then,

$$(1)\quad a' = \frac{100\,a}{A}, \text{ and}$$

$$(2)\quad b' = \frac{100\,b}{B}$$

Combining equations (1) and (2) we have,

$$(3)\quad a' + b' = \frac{100\,a}{A} + \frac{100\,b}{B}$$

But B =A, since both curves are constructed on a percentage basis. Therefore,

$$(4)\quad a' + b' = \frac{100\,(a + b)}{A}$$

Dividing both sides of equation (4) by 2, we have

$$(5)\quad \frac{a' + b'}{2} = \frac{100\,(a + b)}{2A}$$

But $\frac{a' + b'}{2}$ equals my index of intergradation by definition. This means that this index of intergradation, when graphically presented, equals the percentage of the area overlapped by the two curves into the sum of the areas of both curves constructed on a percentage basis.

Index of Divergence.—Regarding my index of divergence, by definition it equals 100 minus the index of intergradation, that is,

$$\text{Index of divergence} = 100 - \frac{100\,(a + b)}{2A}$$

$$= \frac{100\,[2A - (a + b)\,]}{2A}$$

This means that, graphically presented, the index of divergence equals the percentage of the combined areas of the two curves diminished by the overlapped area, into the combined areas of the two curves. In other words, by reference to Text-fig. 1, it equals the percentage of areas *cgd* + *chd* into A + B.

Practical Use of Indices.—I have used these two indices with satisfactory results in drawing taxonomic conclusions in the following papers cited below: 1944: 376; 1950: 504 and 518; 1951: 198 (on last page cited "index of divergence" erroneously printed for "index of intergradation"); 1952: 94; 1953: 35. In addition to the pages cited where the indices are formally applied, I applied them tacitly in drawing taxonomic conclusions in other places, from the determined data. In general, I found the idea of the use of these indices and their practical application of much help in the pursuit of my studies.

In my original paper (1938), I suggested two ways of calculating the index of intergradation in practice. By one method the following steps are taken. (1) Arrange the data for the two populations compared in a frequency distribution table. (2) From the arranged data in the table construct two overlapping curves representing the two respective populations. (3) Draw a vertical dividing line in the table at a point corresponding to the point of intersection of the two curves, as the heavy vertical line in Tables I and II, the dividing line in our hypothetical example being between the classes 20 and 21. (4) Calculate the percentage of those intergrading specimens that cross the dividing line in each distribution, namely, the specimens to the right of the dividing line in alpha and those to the left of the line in beta, into the total number of specimens in each respective distribution. (5) Add the numbers thus obtained and divide by two. Another way is to tabulate the frequencies in the form of percentage as in Table II, add the smaller of the overlapping frequencies and divide the sum by 2. Applying either method to the assumed data here considered, the index of intergradation shown by the two sets of data is 14 and is of subspecies magnitude, near the lower limit of that magnitude, as previously proposed by me (1938).

The index of divergence may be calculated in two ways complementary to that in which the index of intergradation is calculated, as follows: (1) By reference to Table I, calculate the percentage of the specimens of alpha that are to the left of the dividing line, into the total number of specimens in that sample. Likewise, calculate the percentage of the specimens of beta that are to the right of the dividing line, into the total number of specimens in its sample. Add the two numbers thus obtained and divide by 2. (2) By reference to Table II, add the percentages of the frequencies to the right and to the left of the dividing line, for alpha and beta, respectively, and divide by two. Another way to determine the index of divergence is to first determine the index of intergradation and subtract it from 100. Whichever method is used, the index of divergence of alpha and beta is 86, which is of subspecies magnitude according to the schedule previously proposed by me (1938), near the higher end of that magnitude.

Two Alternative Procedures.—Instead of expressing the index of intergradation as the percentage of the overlapped area into the sum of areas A and B, it may be expressed as the percentage of the overlapped area into one of these areas, namely A, which equals B. In that case the index of intergradation is expressed by the above equation (4), and the step of dividing by 2, as in equation (5), is omitted. The effect of this procedure is to have this index doubled in its numerical value.

Starting with this latter possible index of intergradation, two possible indices of divergence may be proposed.

One method is to propose an index of divergence as represented by the following equation:

Index of divergence = 200–Index of intergradation

$$= 200 - \frac{100\,(a+b)}{\text{A}}$$

$$= \frac{100\,[2\text{A} - (a+b)]}{\text{A}}$$

This possible index of divergence then represents the percentage of the sum of the areas of the two curves diminished by the overlapped area, into one of the curves. The effect of this procedure is to double the numerical value of the index of divergence also, as compared with the procedure originally proposed and discussed above.

The second possible method is to have the index of divergence represented by the following equation:

Index of divergence = 100–Index of intergradation

$$= 100 - \frac{100\,(a+b)}{\text{A}}$$

$$= \frac{100\,[\text{A} - (a+b)]}{\text{A}}$$

This latter possible index of divergence then is represented as the percentage of the area of one of the curves diminished by the overlapped area, or in other words, as the percentage of the area of that part of one curve that is not overlapped, into the area of one curve.

Which one of the above three methods, the one originally employed and the possible two here suggested, is best, is not clear to me at present. Perhaps this could be ascertained by their application to an adequate series of comparable pairs of populations. As these indices merely have a relative, instead of an absolute, value, it is probable that it would not make much difference which one is employed as long as the same one is used consistently throughout for comparative purposes. The one originally proposed and considered at greater length above seems to be rather more compact and expressive and is perhaps preferable. In reality the three methods are merely modifications of the same basic method. They are all based on a determination, in different ways, of the relation of the overlapped area to the area of one curve or both curves combined.

It is interesting to note that by the use of the original method, the index of intergradation cannot exceed 50, while the index of divergence cannot be less than 50. By the first one of the two alternative methods the index of intergradation runs the gamut of 0 to 100; while the index of divergence cannot be less than 100. By the second of the alternative methods both indices will differ in value from 0 to 100.

Short Cut.—Expressing the frequencies in the form of percentages, as in Table II, is advantageous in that the various numbers concerned in the analysis of Text-fig. 1 may be readily determined directly from the table. Thus, the value of a equals the sum of the values in alpha that are located to the right of the dividing line which in the hypothetical example equals 9. The value of b equals the sum of the values in beta to the left of the dividing line, namely, $12.7 + 5.4 = 18.1$. The numerical value of the part of the curve that is not overlapped equals $100-(a + b) = 100-(9 + 18.1) = 72.9$.

Acknowledgment.—I wish to express my grateful appreciation to Arthur Schach and to Ralph P. Silliman who read successive trial versions of the manuscript and made constructive suggestions for its clarification.

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Reprinted from Journal of the Washington Academy of Sciences
Volume 44, No. 8, August 1954
Printed in U.S.A.

ICHTHYOLOGY.—*Four new fishes and one little-known species from the east coast of the United States including the Gulf of Mexico.* Isaac Ginsburg, U. S. Fish and Wildlife Service. (Communicated by L. P. Schultz.)

The specimens on which the four new species here described are based, were obtained by the *Albatross III* on the coast of South Carolina and by the *Oregon* in the Gulf of Mexico and are deposited in the United States National Museum, including the four holotypes, except one paratype from the coast of Massachusetts deposited in the Museum of Comparative Zoology and three paratypes from the Gulf of Mexico in the University of Miami. The illustrations accompanying this paper were drawn by Mildred H. Carrington.

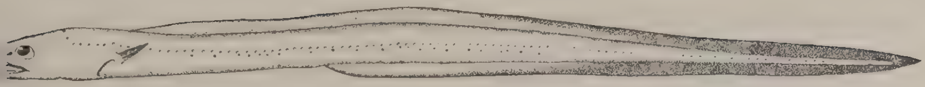
Family Congridae

Uroconger syringinus, n. sp.

The terminology and methods of study and measurements used in examining and describing this species are the same as used in my account of the eels of the northern Gulf coast (1951).

Description.—Trunk compressed to subterete, depth moderate. Tail well tapering, comparatively long, body 1.4–2.0 times in tail. Eye moderately large, 1.6–2.5 times in snout. Mouth rather large, its angle placed under middle of eye or slightly more backward. Jaws of medium extent; lower jaw moderately shorter than upper, 2.4–2.9 times in head. Snout blunt, 3.3–3.9 times in head, extenting moderately beyond lower jaw; premaxillary teeth exposed with the mouth closed, placed close to margin of upper jaw. Upper lip not forming an upturned fold, covered entirely by a broad fold of skin descending from the cheek; two tips of prolongations from buccal ossicle impinging on distal outline of fold and readily appreciable on external inspection; lower lip confined to the side of the jaw, falling considerably short of end of jaw, forming a broad fold deflected downward. Posterior nostril placed in front of and near eye, on a horizontal through middle of eye or slightly above its middle, its margin slightly or hardly raised; anterior nostril placed nearly on lateral aspect not far from end of snout, with a membranous well raised margin. A large pore directly over anterior nostril, extending partly more forward then nostril; a somewhat smaller pore at some distance behind and slightly higher; a medium sized pore directly behind anterior nostril; three very large elongate apertures at edge of cheek fold, the first near to medium sized pore, the third under anterior part of eye. Tongue free, rather well developed. Gill opening almost transverse, mainly lateral, rather large, slightly smaller or larger than distance between the two fellows. Dorsal origin on a vertical at a short or moderate distance behind pectoral base. Dorsal, anal and caudal continuous, of medium development except caudal moderately long (for an eel). Pectoral placed behind gill opening, at its upper angle, rather narrow, its length subequal to snout or slightly longer. Teeth slender, sharp, spaced, the anterior teeth generally rather large caninoid; teeth on side of both jaws in two well separated rows, the teeth in the rows similar, rather large anteriorly gradually or rather irregularly changing to posterior smaller teeth, posterior teeth in outer row smaller than those in inner row. In lower jaw the rows continued around symphysis but the two-rowed arrangement not as sharply marked there and the front teeth smaller than the anterior lateral teeth; a third lengthwise row of 4 or 5 teeth at anterior part of lower jaw, near midline, the teeth in this row becoming larger posteriorly, the two fellow rows somewhat diverging posteriorly, the hindmost two teeth in the third row largest of any in lower jaw. Upper jaw with anterior lateral 5 to 8 teeth graduated, growing larger posteriorly, thence gradually decreasing in size. Premaxillary teeth rather well separated from jaw and palatal teeth; in two transverse, nearly parallel, curving rows, 5 to 7 teeth in a row, teeth in outer row smaller, outer tooth of inner row largest of any in upper jaw. Palatal teeth preceded by one caninoid on midline or two caninoids, one behind the other, the anterior caninoid generally flanked on both sides by one smaller tooth, the one or two caninoids followed after a variable interval by a single median row of rather small, sharp teeth extending approximately to a variably placed vertical plane through eye.

Measurements of two specimens 255–279 mm, two specimens 313–333 mm, and one specimen 416 mm; the following proportional measurements given in three groups in the same order, respectively: body 37–41, 37.0–39.5, 33.5; trunk 23.0–25.5, 24.0–24.5, 21.5; tail 59–63, 60–63, 67; antedorsal 15.0–16.9; 15.4–16.0, 13.3; head



'IG. 1.—*Uroconger syringinus*, n. sp., from the holotype (U.S.N.M. 157781) from off Mississippi Delta, 50 fathoms (28° 45′ N., 89° 43′ W.); 279 mm.

3–16.4, 13.5–14.7, 13.6; upper jaw 5.4–7.3, -6.1, 5.2; lower jaw 4.9–6.8, 5.3–5.7, 4.9; ut 3.8–4.6, 3.9–4.3, 3.5; eye 1.9–2.3, 2.1–2.3, ; depth 4.4–4.8, 5.0–5.3, 5.0; pectoral 3.7–4.8, , 3.5; caudal 2.8–3.4, 3.4–5.0, 2.3; body in 1.4–1.7, 1.5–1.7 and 2.0 times; snout in d 3.6–3.8, 3.3–3.4 and 3.9 times; lower jaw in d 2.4–2.9, 2.4–2.6 and 2.8 times; eye in snout -2.4, 1.6–2.1 and 2.5 times.

revailing color yellowish or grayish; ventral ect and posterior part of tail with a lilaceous ge more or less developed; head with a faint ce of lilaceous; greater posterior part of trunk l anterior part of tail with a lengthwise irular row of very small dark dots, few or in derate numbers, irregularly spaced, placed newhat below midline; caudal and posterior t of dorsal and anal black.

Holotype.—U.S.N.M. 157781. *Oregon* station lat. 28° 45′ N., long. 89° 43′ W.; off Missispi Delta; 50 fathoms; May 28, 1950; 279 mm.

Paratypes.—Off Port Isabel, Tex.; 55 fathoms; pecimen 333 mm (U.S.N.M. 157789). Gulf of exico (exact locality uncertain) 3 specimens 5–416 mm (University of Miami).

Remarks.—A state of confusion appears to st in the literature regarding the species herto placed in *Uroconger*. Richardson (1844:) in describing his *Conger lepturus* stated that ias two or three teeth on the palate ("vomer"). up (1856: 110) paraphrased briefly Richard's description and established his monotypic ius *Uroconger* based solely on this description. eeker (1864: 29) and also Day (1878: 661) lowed by later, including very recent, authors the name *Uroconger lepturus* for a species ving a row of teeth on the palate, instead of two three teeth as described by Richardson. Vailt (1888: 86) described his *Uroconger vicinus* also having two teeth on the palate. This roborates Richardson's account in that at st one species with only two teeth on the ate does exist. Vaillant's *vicinus* might be the ne as Richardson's *lepturus* or it might repret a distinct and closely related species; while *U. lepturus* of Bleeker, Day and other authors most likely a different species, possibly the same as *Congerodon indicus* Kaup (Arch. Naturg. **22** (1): 74. 1856).

The species here described differs from *Uroconger lepturus* (Richardson) in having a row of palatal teeth, instead of two or three. In this respect it agrees with the *U. lepturus* of authors (not Richardson). A specimen (269 mm) of what appears to be the latter species (U.S.N.M. 135309, taken off the southwest coast of Celebes) differs from *syringinus* as follows: body 30.5, tail 69.5, trunk 19.0, antedorsal 12.7, head 12.4. This species, then, has a longer tail and shorter body, trunk, antedorsal distance and head as compared with *syringinus*. The posterior part of the tail in this specimen is more attenuated as compared with the type of *syringinus* of nearly equal size.

In my recently published key to the Congridae of the northern Gulf of Mexico (1951: 437) the species here described falls in between *Congermuraena impressa* and the genus *Congrina*. It agrees with *Congrina* in that a broad fold descending from the cheek covers the upper lip

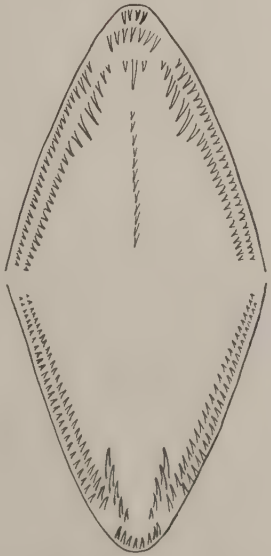


FIG. 2.—*Uroconger syringinus*, n. sp., dentition; semi-diagrammatic.

Reprinted from JOURNAL OF THE WASHINGTON ACADEMY OF SCIENCES
Volume 44, No. 8, August 1954
Printed in U.S.A.

ICHTHYOLOGY.—*Four new fishes and one little-known species from the east coa of the United States including the Gulf of Mexico.* ISAAC GINSBURG, U. S. Fi and Wildlife Service. (Communicated by L. P. Schultz.)

The specimens on which the four new species here described are based, were obtained by the *Albatross III* on the coast of South Carolina and by the *Oregon* in the Gulf of Mexico and are deposited in the United States National Museum, including the four holotypes, except one paratype from the coast of Massachusetts deposited in the Museum of Comparative Zoology and three paratypes from the Gulf of Mexico in the University of Miami. The illustrations accompanying this paper were drawn by Mildred H. Carrington.

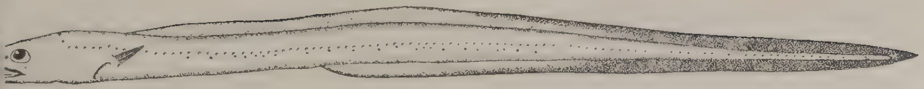
Family CONGRIDAE

Uroconger syringinus, n. sp.

The terminology and methods of study and measurements used in examining and describing this species are the same as used in my account of the eels of the northern Gulf coast (1951).

Description.—Trunk compressed to subterete, depth moderate. Tail well tapering, comparatively long, body 1.4–2.0 times in tail. Eye moderately large, 1.6–2.5 times in snout. Mouth rather large, its angle placed under middle of eye or slightly more backward. Jaws of medium extent; lower jaw moderately shorter than upper, 2.4–2.9 times in head. Snout blunt, 3.3–3.9 times in head, extenting moderately beyond lower jaw; premaxillary teeth exposed with the mouth closed, placed close to margin of upper jaw. Upper lip not forming an upturned fold, covered entirely by a broad fold of skin descending from the cheek; two tips of prolongations from buccal ossicle impinging on distal outline of fold and readily appreciable on external inspection; lower lip confined to the side of the jaw, falling considerably short of end of jaw, forming a broad fold deflected downward. Posterior nostril placed in front of and near eye, on a horizontal through middle of eye or slightly above its middle, its margin slightly or hardly raised; anterior nostril placed nearly on lateral aspect not far from end of snout, with a membranous well raised margin. A large pore directly over anterior nostril, extending partly more forward then nostril; a somewhat smaller pore at some distance behind and slightly higher; a medium sized pore directly behind anterior nostril; three very large elongate apertures at edge of cheek fold, the first near medium sized pore, the third under anterior pa of eye. Tongue free, rather well developed. Gi opening almost transverse, mainly lateral, rathe large, slightly smaller or larger than distanc between the two fellows. Dorsal origin on vertical at a short or moderate distance behin pectoral base. Dorsal, anal and caudal continuou of medium development except caudal moder ately long (for an eel). Pectoral placed behind gi opening, at its upper angle, rather narrow, it length subequal to snout or slightly longe Teeth slender, sharp, spaced, the anterior teet generally rather large caninoid; teeth on side o both jaws in two well separated rows, the teet in the rows similar, rather large anteriorly gradu ally or rather irregularly changing to posterio smaller teeth, posterior teeth in outer row smalle than those in inner row. In lower jaw the row continued around symphysis but the two-rowe arrangement not as sharply marked there an the front teeth smaller than the anterior latera teeth; a third lengthwise row of 4 or 5 teeth a anterior part of lower jaw, near midline, the teet in this row becoming larger posteriorly, the tw fellow rows somewhat diverging posteriorly, th hindmost two teeth in the third row largest o any in lower jaw. Upper jaw with anterior latera 5 to 8 teeth graduated, growing larger posteriorly thence gradually decreasing in size. Premaxillary teeth rather well separated from jaw and palata teeth; in two transverse, nearly parallel, curving rows, 5 to 7 teeth in a row, teeth in outer row smaller, outer tooth of inner row largest of any in upper jaw. Palatal teeth preceded by one caninoid on midline or two caninoids, one behind the other the anterior caninoid generally flanked on both sides by one smaller tooth, the one or two caninoids followed after a variable interval by a single median row of rather small, sharp teeth extending approximately to a variably placed vertica plane through eye.

Measurements of two specimens 255–279 mm, two specimens 313–333 mm, and one specimen 416 mm; the following proportional measurements given in three groups in the same order, respectively: body 37–41, 37.0–39.5, 33.5; trunk 23.0–25.5, 24.0–24.5, 21.5; tail 59–63, 60–63, 67; antedorsal 15.0–16.9; 15.4–16.0, 13.3; head



IG. 1.—*Uroconger syringinus*, n. sp., from the holotype (U.S.N.M. 157781) from off Mississippi Delta, 50 fathoms (28° 45′ N., 89° 43′ W.); 279 mm.

3–16.4, 13.5–14.7, 13.6; upper jaw 5.4–7.3, -6.1, 5.2; lower jaw 4.9–6.8, 5.3–5.7, 4.9; ut 3.8–4.6, 3.9–4.3, 3.5; eye 1.9–2.3, 2.1–2.3, ; depth 4.4–4.8, 5.0–5.3, 5.0; pectoral 3.7–4.8, , 3.5; caudal 2.8–3.4, 3.4–5.0, 2.3; body in 1.4–1.7, 1.5–1.7 and 2.0 times; snout in d 3.6–3.8, 3.3–3.4 and 3.9 times; lower jaw in d 2.4–2.9, 2.4–2.6 and 2.8 times; eye in snout -2.4, 1.6–2.1 and 2.5 times.

Prevailing color yellowish or grayish; ventral ect and posterior part of tail with a lilaceous ge more or less developed; head with a faint ce of lilaceous; greater posterior part of trunk d anterior part of tail with a lengthwise ir- ular row of very small dark dots, few or in derate numbers, irregularly spaced, placed newhat below midline; caudal and posterior rt of dorsal and anal black.

Holotype.—U.S.N.M. 157781. *Oregon* station ; lat. 28° 45′ N., long. 89° 43′ W.; off Missis- pi Delta; 50 fathoms; May 28, 1950; 279 mm.

Paratypes.—Off Port Isabel, Tex.; 55 fathoms; specimen 333 mm (U.S.N.M. 157789). Gulf of exico (exact locality uncertain) 3 specimens 5–416 mm (University of Miami).

Remarks.—A state of confusion appears to ist in the literature regarding the species therto placed in *Uroconger*. Richardson (1844: 6) in describing his *Conger lepturus* stated that has two or three teeth on the palate ("vomer"). aup (1856: 110) paraphrased briefly Richard- n's description and established his monotypic nus *Uroconger* based solely on this description. leeker (1864: 29) and also Day (1878: 661) llowed by later, including very recent, authors e the name *Uroconger lepturus* for a species ving a row of teeth on the palate, instead of two three teeth as described by Richardson. Vail- nt (1888: 86) described his *Uroconger vicinus* also having two teeth on the palate. This rroborates Richardson's account in that at ast one species with only two teeth on the alate does exist. Vaillant's *vicinus* might be the me as Richardson's *lepturus* or it might repre- nt a distinct and closely related species; while e *U. lepturus* of Bleeker, Day and other authors most likely a different species, possibly the same as *Congerodon indicus* Kaup (Arch. Naturg. **22** (1): 74. 1856).

The species here described differs from *Uroconger lepturus* (Richardson) in having a row of palatal teeth, instead of two or three. In this respect it agrees with the *U. lepturus* of authors (not Richardson). A specimen (269 mm) of what appears to be the latter species (U.S.N.M. 135309, taken off the southwest coast of Celebes) differs from *syringinus* as follows: body 30.5, tail 69.5, trunk 19.0, antedorsal 12.7, head 12.4. This species, then, has a longer tail and shorter body, trunk, antedorsal distance and head as compared with *syringinus*. The posterior part of the tail in this specimen is more attenuated as compared with the type of *syringinus* of nearly equal size.

In my recently published key to the Congridae of the northern Gulf of Mexico (1951: 437) the species here described falls in between *Congermuraena impressa* and the genus *Congrina*. It agrees with *Congrina* in that a broad fold descending from the cheek covers the upper lip

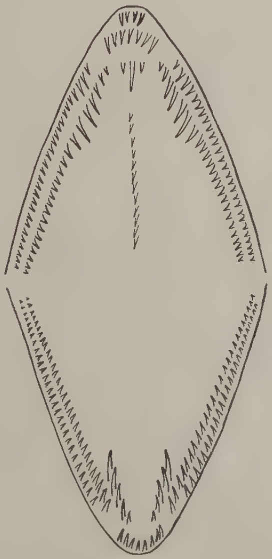


FIG. 2.—*Uroconger syringinus*, n. sp., dentition; semi-diagrammatic.

and contains extensions from the buccal ossicle that are readily appreciable on external examination. Also, the caudal is comparatively well developed as in *Congrina*. It differs from *Congrina* in the dentition in its sharp, slender teeth in 2 rows in upper jaw, three rows in lower jaw and nearly a single row on palate. The premaxillary teeth are placed near the end of the upper jaw instead of at some distance behind the end. The extent to which the snout projects beyond the lower jaw is about intermediate as compared with *Congrina* on the one hand and *Congermuraena* on the other.

In this species the relative length of the tail appears to increase with growth which is contrary to growth changes in other eels (see Ginsburg, 1951: 444 and passim).

Family Stromateidae

Genus **Cubiceps** Lowe

Cubiceps Lowe, Proc. Zool. Soc. London **11:** 82. 1843. (Genotype, *Seriola gracilis* Lowe by monotypy. The species is described under the above name; but the author suggests that it might belong to a separate genus and if so he proposes the name *Cubiceps* for it.)

The following description is based on and includes the characters common to the two species here treated.

Description.—Elongate, compressed, somewhat spindle shaped, but tapering more posteriorly than anteriorly. Eye large, its adipose margin moderately developed. Snout blunt, slightly longer than eye. Mouth small, moderately inclined, terminal, the jaws equal or lower jaw slightly projecting. Maxillary falling short of a vertical through anterior margin of eye, of moderate width, slipping for its entire length and greater part under suborbital, leaving a narrow or slight outer strip exposed; supplemental maxillary very thin, almost membranous, rather broad and of moderate length. Teeth small, of nearly uniform size, compressed, moderately pointed or rather blunt, close-set, in a single row in jaws; none on vomer and palatine. Opercular series of bones notably thin and flexible. Opercle with a well emarginate area at its posterior end, bridged over by a thin membranous area; without spines; its anterior part with slight ridges somewhat diverging backward. Gill opening wide; branchiostegal membranes separate all the way forward, continued to chin, the inner edge of the two fellows about parallel at their anterior extent. Pseudobranchiae well developed. Gill rakers well developed, eas
countable including those at the ends of the ar
moderately long at angle gradually decreas
in size both ways. Pharynx muscular, bulging,
inner surface with thick, rather low, colum
bodies bearing slender, short, spine-like tee
Mid-ventral line with a furrow between a
and pelvic fins. Scales cycloid, large to mediu
about 39–68 oblique rows over lateral line; bo
including chest completely scaled, on antedor
area scales extending to opposite anterior mar
of pupil or eye; cheek scaled; snout scalel
densely beset with small pores; opercle proba
without scales, in large part anyway; base
second dorsal and anal fins with a densely sca
sheath; caudal scaled in large part, pectoral a
pelvic fins scaled for some distance at their ba
lateral line placed high, two longitudinal rows
scales between it and dorsal base, the scales w
profusely branched channels. (Most or nea
all scales are missing in all specimens exami
and some of the above statements are ba
largely on a study of the scale pockets. T
extent of scalation on the opercle, if any, is
definitely determinable. The lateral line is b
preserved in the holotype of *nigriargenteus*,
greater part, to about the twenty fifth scale,
the course of its posterior part is not determina
in any specimen.) Two completely separ
dorsal fins; first dorsal with 11 more or less flexi
spines, the anterior 4 unevenly graduated, fi
subequal to fourth, thence gradually and rapi
decreasing in length to last; second dor
comparatively rather low, the first ray flexi
or rather stiff, usually unjointed, presumably
spine homologically (in one specimen of *nigri*
genteus the first ray jointed), followed by
jointed and mostly branched rays, the rays rat
widely spaced, posterior few rays somew
thickened, the last ray notably thick and lon
than preceding rays. The three anal spines st
pungent or the third somewhat flexible, uneve
graduated, anterior two short, the second a lit
longer than the first the third considera
longer, followed by 14 or 15 jointed rays, the s
rayed part of anal similar to second dors
Base of second dorsal and anal with a series
somewhat oval shaped or rounded fossae,
corresponding pair from the two sides usua
continuous resulting in a series of perforatio
every perforation placed between an adjac
pair of rays, at their bases. Pelvic reach
about half the distance from its base to a
origin or a little more; its outer spine more or l

ble, falling moderately short of its apex; its r angle a little behind lower pectoral angle, . vertical nearly through origin of first dorsal little behind. Pectoral reaching a vertical at e distance behind end of pelvic; moderately ite, the lower rays short, the longest rays a e below upper margin. Caudal with a deep haped incision or well lunate.

emarks.—It is doubtful whether the two ies here treated are congeneric with *C. ilis* (Lowe), the genotype of *Cubiceps*. How-, the necessary material is unavailable to pare our two species with *gracilis* and to perly resolve the question of the limits of *iceps* and its synonymy. The following two ies are therefore only tentatively allocated his genus.

Cubiceps nigriargenteus, n. sp.

) XI; (0) I 15 (16). A III 15. P 21–22. Sc about 56. GR 9–10 + 17–19.

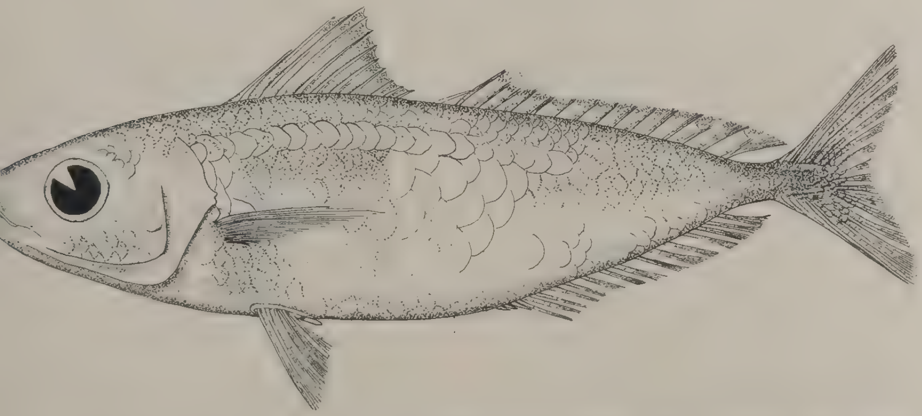
escription.—First dorsal and anal counts stant in the eight specimens examined. ond dorsal typically with one flexible spine 1 15 segmented rays (in 7); in one variant S.N.M. 157775) the first fin support also a nted (and unbranched) ray. Pectoral rays 22 5) or 21 (in 3). Roughly about 39–56 oblique s of scales over lateral line (not possible to ermine the number with anything approaching uracy as discussed below). Gill rakers 9 + 17, + 18, 9 + 19 and 10 + 19 (the four counts ed in two specimens each). Beginning of scala- n on dorsal aspect in a somewhat curved line situated over anterior margin of pupil, varying very slightly both ways.

Measurements of four specimens 138–174 mm and four specimens 199–229 mm, those of the smaller specimens in parentheses: caudal 22 in 1 (22–25 in 2), pectoral 23.5–25.0 (22.0–26.5), pelvic 14.2–14.9 (14.6–16.7), depth 26.0–27.5 (26.5–29.5), head 28.5–32.0 (29.5–32.0), maxillary 7.7–8.7 (7.2–7.9), snout 8.8–9.4 (8.6–9.6), eye 7.3–8.4 (7.6–8.6), interorbital 9.0–10.3 (9.0–9.9), antedorsal distance 32.5–33.5 (33–34), preanal distance (tip of snout to anal origin) 62–65 (60–63).

Color of the eight preserved and largely or almost wholly desquamated specimens as follows: Lower part of body and head silvery, upper part dark to nearly black, the more or less distinct boundary between the two colors being a nearly median longitudinal line. The above color pattern present in 6 specimens 138–221 mm. Two specimens 205–229 mm have a dusky color with the lower part only moderately lighter than the upper part and the color changing rather gradually from the back to the ventral aspect. No distinctive color marks.

Holotype.—U.S.N.M. 151954; off Cape Romain, S. C.; 92 fathoms; *Albatross III*; January 30, 1950; 189 mm in standard length; about 229 mm in total length.

Paratypes.—Sandwich, Mass., in fish trap (M.C.Z. 37183). Off Santa Rosa Island (U.S.N.M. 157774–5) and Pensacola (U.S.N.M. 157777), Fla.; taken by the *Oregon*. Total examined 7 paratypes 138–221 mm; taken by trawls, except the first one listed, in 112–175 fathoms.



G. 3.—*Cubiceps nigriargenteus*, n. sp., from the holotype (U.S.N.M. 151954), from off Cape Romain, S. C., 92 fathoms; about 229 mm.

Remarks.—This species is near *C. brevimanus* Klunzinger from the Red Sea (Fische des Rothen Meeres: 116, pl. 12, fig. 3. 1884). As compared with the account of that species it differs in having 21 or 22 pectoral rays, instead of 24; and 11 dorsal spines, instead of 10. It is still nearer structurally to *melanus* with which it is compared below under the account of that species.

Cubiceps melanus, n. sp.

D XI; I 15. A III 14–15. P 21–22. Sc about 62–68. GR 9–11 + 18–20.

Description.—Dorsal spines and rays and anal spines constant in the nine specimens examined. Anal rays predominantly 15 (in 7), often 14 (in 2). Pectoral rays predominantly 22 (in 7), often 21 (in 2). Roughly about 62–67 oblique rows of scales over lateral line (not possible to determine the count with precision as discussed below). Gill rakers on upper limb 9 (in 2), 10 (5) or 11 (2); on lower limb 18 (2), 19 (4) or 20 (3); total number on both limbs 27 (1), 29 (5) or 30 (3). Beginning of scalation on dorsal aspect in a somewhat curved line situated over anterior margin of eye, varying very slightly both ways.

Measurements of eight specimens 138–174 mm and 1 specimen 185 mm, those of the smaller specimens in parentheses: caudal (21.5–23.0 in 3), pectoral 22 (22–24 in 6), pelvic 14.5 (13.7–14.8 in 4), depth 26.5 (25.0–28.5), head 31.5 (29.5–32.0), maxillary 9.4 (8.4–9.3), snout 10.6 (9.4–10.1), eye 8.1 (7.0–8.7), interorbital 9.8 (8.8–9.8), antedorsal 35 (33.5-35.5), preanal 64 (61.5–64.5).

Brownish dusky or nearly black, all over, or nearly so, sometimes silvery to some extent on posterior and lower part of opercular series of bones, chest and a narrow area on ventral aspect sometimes washed with silvery shades. No distinctive color marks.

Holotype.—U.S.N.M. 157779; off Mississippi Delta; 190–210 fathoms; *Oregon* station 382; lat. 29° 11′ 30″ N., long. 88° 07′ 30″ W.; June 21 1951; 153.5 mm in standard length, about 185 mm in total length.

Paratypes.—Off Mississippi Delta, *Oregon* stations 480–484 (U.S.N.M. 157780). Off Pensacola, *Oregon* station 314 (U.S.N.M. 157787). Off Cape Romain, S. C., *Albatross III* (U.S.N.M. 151903). Off Cape Lookout, N. C., *Albatross III* (151922). Total examined eight paratypes 138–174 mm taken in 125–200 fathoms.

Remarks.—This species is separable fro *nigriargenteus* with much difficulty. They ar distinguishable chiefly by four differences, namel the size of the scales, the color, the extent o scalation on the interorbital region and th maxillary length. The scale count possibly constitutes the best character for separating them, bu in practice it cannot be applied with precisio because the scales are deciduous and almost a or the greater part of the scales are missing in a specimens examined of both species. The scal pockets also are weak and nearly disappear s that their outlines are generally faint or hardl traceable in preserved specimens. The other differences are slight or not sharply divergent.

The number of scales was determined b counting the oblique rows of the more or les faintly outlined scale pockets above the norma position of the lateral line. In 8 specimens o *nigriargenteus* the determined range is 39–56 in 9 individuals of this species it is 62–68. Whil the two species evidently differ in the number o scales, the given numbers are only very roughl approximate, because of the practical impossibility of making a precise count as stated.

The color of *melanus* is a nearly uniform dusk to black; while in most specimens of *nigriargente* the upper part is dark and the lower part silver the two colors usually being rather sharpl contrasted; but often the dark upper part blend gradually with a somewhat lighter color on th lower part of the body.

In *melanus* the scalation on the dorsal aspec extends approximately to over the anterio margin of the eye; in *nigriargenteus* approximatel to over the anterior margin of the pupil. Thi difference is slight and is appreciable only o direct comparison of specimens. Morover, the is a slight individual variability within the limit of each species.

The maxillary length is 8.4–9.4 per cent the standard length in 9 specimens of *melan* 138–185 mm and 7.2–8.7 in 8 specimens of *nigria genteus* 138–229 mm. This difference then also slight and somewhat intergrading.

Other differences or possible differences th intergrade still more are as follows.

The gill raker count evidently averages high in *melanus* as may be gathered by the data give under the two species. While the two specie intergrade considerably in these numbers, th few specimens examined would seem to sugge

egree of divergence of at least subspecies
gnitude.

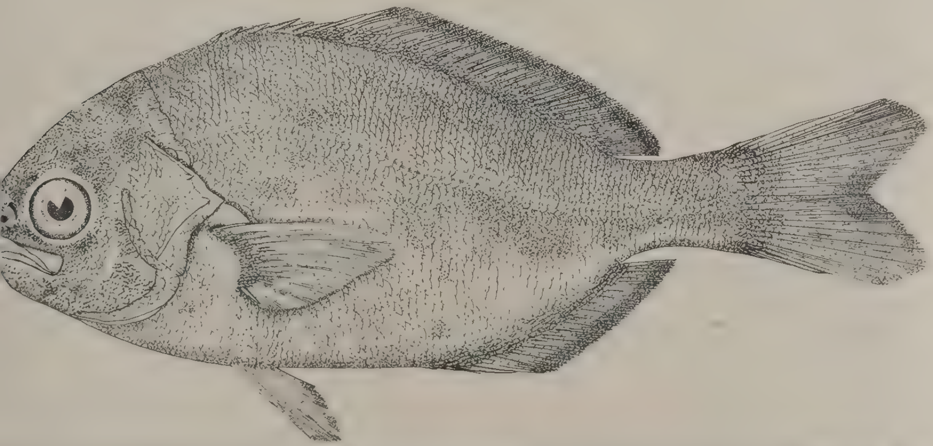
wo out of nine specimens of *melanus* have 14
l rays, while in eight specimens of *nigri-*
nteus the count is constantly 15.

The few specimens measured suggest some
sible slight average differences as follows:
anus having shorter fins, a slenderer body,
ger snout and longer antedorsal. But these
erences, if any, evidently are widely inter-
ding.

Palinurichthys bythites, n. sp.

D VI; I 23–25. A III 17. P 21–22. Sc 85–87.
7 + 16–17.

Description.—Body and caudal peduncle
her deep and compressed. Snout short, notably
tuse, its anterior aspect broad and nearly
tical (resembling that of a pompano). Eye
ge, subequal to or slightly smaller than
out. Adipose eyelid slight. Maxillary of mod-
te width, rather short, ending under middle
eye, exposed for its entire length; no supple-
ntal maxillary, its upper part separated by an
ngate groove but without an evident suture.
eopercle notably expanded, its distal lower
rgin broadly curved, slightly scalloped and
ghtly and rather sparsely serrate. Mouth
all, very moderately inclined, placed low, a
rizontal through distal margin of upper lip
ssing through lower margin of eye; subterminal,
wer jaw slightly included. Teeth small, in one
w in jaws; none on vomer, palatines and
tongue. Gill opening broad, branchiostegal membranes united under eye. Pseudobranchiae moderate. Gill rakers well developed, broad, compressed, 7 + 16–17, including one small gill raker at either end of the arch. Pharynx muscular, bulging, its inner surface with low hummock-like projections, each with a group of sharp spine-like teeth. Scales cycloid, small, in 85–87 oblique rows over lateral line to caudal base (scales largely deciduous and count based on rows of scale pockets); body, including belly, chest, fleshy pectoral base and posterior part of predorsal area, almost altogether scaled, the squamation extending to a transverse, moderately oblique line a little behind upper angle of gill opening; a scaled strip at posterior boundary of cheek continued upward along preopercular margin behind eye; (opercle probably scaled, perhaps in part, skin on opercle destroyed in large part and scalation there indeterminable); rest of head naked; caudal scaled in its larger, proximal part; other fins scaled at their base. Head, from boundary of scalation forward, thickly beset with many pores forming openings to short, irregular channels under the skin. Lateral line slightly sinuous; its curve very moderately elevated, long, gradually merging with posterior straight part approximately over middle of anal base. Dorsal with anterior 6 spines well spaced, moderately stout, short, partly disconnected distally from one another, slightly graduated from first to fourth, fifth and sixth subequal to fourth; seventh spine abruptly



IG. 4. *Palinurichthys bythites*, n. sp., from the holotype (U.S.N.M. 157776), from off Pensacola, Fla., 220 fathoms (29° 27′ N., 87° 19′ W.); 253 mm.

longer and slenderer, closely approximated to soft rays (here considered part of second dorsal); the two dorsals continuous; anterior few soft rays graduated growing longer posteriorly, thence very slowly decreasing in length, first ray segmented and unbranched, others branched, last two rays rather thickened and closely approximated (here counted as two branches of one ray). Anal similar to dorsal except that the three spines well graduated connected to one another; spines and soft rays forming one continuous fin, and all rays including the first, branched. Ventral rather well developed, falling moderately short of anus. Pectoral broad, fifth or sixth ray longest, its distal oblique margin a nearly straight line, its length moderate, reaching a point approximately over anus. Caudal rather well emarginate, shorter than head.

Depth 43.0–45.5, head 32.0–32.5, depth of caudal peduncle 11.5–12.4, maxillary 12.0–12.4, snout 8.7–9.2, eye (measured between soft margins of lid) 7.8–8.7 (3.84–4.22 times in head), interorbital 11.8–13.7, ventral 20–21, pectoral 25.5-27.0, caudal 26–27.

Yellowish above, silvery below, the fins more or less dusky; no distinctive markings. (Nearly all scales are missing on the upper part of body and if any color pattern was present in life it might have been obliterated.)

Holotype.—U.S.N.M. 157776. *Oregon* station 321, lat. 29° 27′ N., long. 87° 19′ W.; off Pensacola, Fla.; 220 fathoms; April 28, 1951; 253 mm.

Paratype.—*Oregon* station 351, lat. 29° 13′ N., long. 88° W.; east of Mississippi Delta; 200 fathoms; May 22, 1951; 239 mm (U.S.N.M. 157778).

Stewart Springer states in a letter that this species appears to be common at about 220 fathoms.

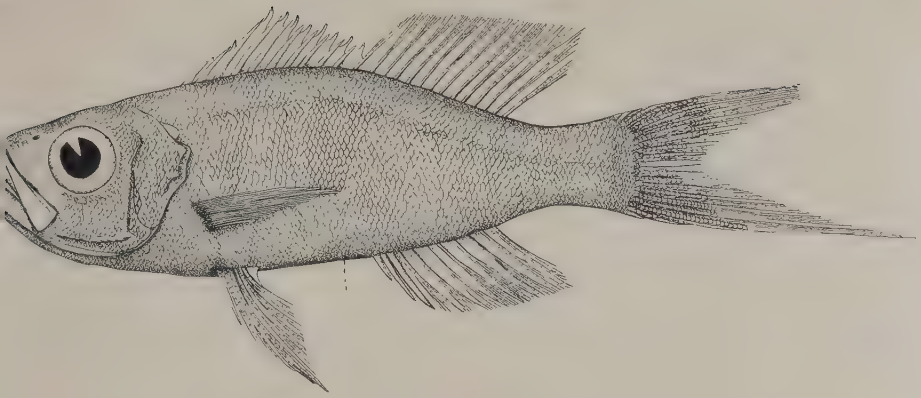
Remarks.—By the shape of its snout particularly, and the short partly disconnected dorsal spines, this species resembles a pompano. However, the scales are larger and the caudal fin not as deeply forked as in pompanos, and the anterior dorsal and anal rays are not produced into prominent lobes. By the presence of sharp, spine-like esophageal teeth and by other characters this species properly belongs to the Stromateidae.

This species is apparently near *Palinurichthys pringlei* Smith (1949a: 304, fig. 849; 1949b: 844) from off Dassen Island, South Africa, and differs in having more gill rakers and possibly a somewhat deeper body. In the three species o this genus examined, namely, *bythites*, *perciform* and *ovalis*, six specimens in all, the gill rake count is comparatively constant 6–7 + 16–1 (counted on both sides) while in the one specimen of *pringlei* recorded it is 7 + 14–15.

As compared with *Palinurichthys perciformi* (De Kay) from the northwestern Atlantic, thi species differs at a glance by its deeper bod and larger eye. It also has the short spines on less and the soft dorsal rays are more numerou In three specimens of *perciformis* 230–287 mm from Ocean City, Md. (U.S.N.M. 57805) Barnegat Bay, N. J. (U.S.N.M. 104910) an Le Have, Nova Scotia (U.S.N.M. 22650) Depth 37.5–38.0; eye 6.1–7.1, 4.61–4.81 times i head. D VII; I 21–22.

A specimen 274 mm in standard length wit the caudal damaged (probably near 345 mm long), labeled *Mupus ovalis* in the Nationa Museum (23323), nearly agrees with Regan description of his *Lirus ovalis* (1902: 198). It counts and measurements are: Depth 45; ey 6.3, 4.64 times in head. D VI; I 31; A III 2 This species then has a higher dorsal and ana count than *bythites* and *perciformis*. Its bod depth is as in *bythites* while the size of the eye a in *perciformis*. It further differs from the tw western Atlantic species in that the last thre short spines are somewhat graduated growin slightly larger posteriorly while in the latter tw species the corresponding three spines are subequal or they grow slightly smaller posteriorly but this difference is slight. The soft dorsal i this specimen is damaged, but the longest ray seem to be near its middle, instead of near it anterior part as in the two American specie But this difference also is slight. There seem t be no well-marked generic differences betwee the specimen labeled *ovalis* and *bythites* an *perciformis*.

The generic name to be used for the three species examined is uncertain. *Leirus* Lowe is preoccupied, hence it or its emended form *Lir* is unavailable. Under his account of *Lir* Regan (1902: 195) lists *Mupus* Cocco, *Schedophilus* Cocco, *Crius* Valenciennes and *Palinur* De Kay as synonyms, in chronological orde Therefore *Mupus* would seem to be the ne name to be considered as a generic name for th above three congeneric species. Cocco's paper i unavailable to me for examination. Accordin to Jordan (1919: 178) the type of *Mupus* i



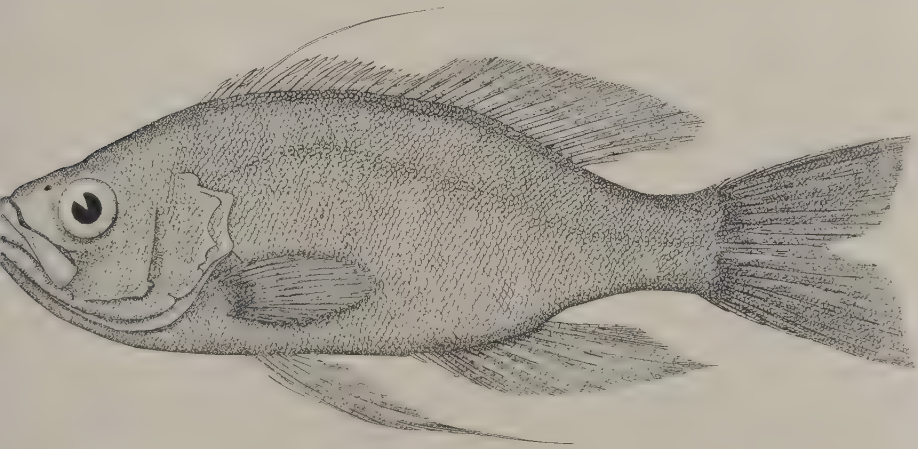
. 5.—*Anthiasicus leptus* Ginsburg, from the holotype (U.S.N.M. 134189), off Dauphin Island, Ala., 68 fathoms (29° 14′ 30″ N., 88° 09′ 30″ W.); about 160 mm, 108 mm in standard length.

imperialis Cocco. The latter name is tenta- ely placed in the synonymy of *Lirus ovalis* Regan (1902: 198). Consequently, according these authors *Mupus* would seem to be prop- y applied to the three species here considered. wever, neither Regan nor anybody else to knowledge has determined definitely the onomic status of *Mupus imperialis* Cocco a study of original specimens. Therefore, I e prefer to use for this species the generic me *Palinurichthys* Bleeker, which has been posed as a substitute for the preoccupied me *Palinurus* De Kay, because that name has en most often associated with the American ecies of the genus.

Fowler (1936: 1281) substitutes Cocco's name *imperialis* for *ovalis* "by right of slight priority," also employing the generic name *Mupus*. However, he does not present evidence to prove the synonymy used or to settle the question of priority.

In our present connection attention should be called also to the following accounts:

Palinurichthys griseolineatus Norman (1937: 117), described from the Atlantic coast of South America apparently differs from our species in its more numerous dorsal and anal rays, judged by its description. The species identified by Norman in the same paper as *P. caeruleus* (Guichenot) apparently differs from ours in



. 6.—*Anthiasicus leptus* Ginsburg (U.S.N.M. 157788) from off Cape San Blas, Fla., 112 fathoms (29° 49′ N., 85° 45′ W.); 308 mm, 240 mm in standard length.

that the posterior curve in the lateral line is nearly absent and possibly also in having more numerous dorsal and anal rays. (Norman is uncertain of its counts.)

Toledia macrophthalma Miranda Ribeiro (1915: Stromateidae, p. 5, photo.) described and illustrated by a photograph from a single larger specimen, 680 mm, from the coast of Brazil possibly also represents a related and congeneric species. It apparently nearly agrees in the dorsal and anal counts with *bythites*, but it is evidently a slenderer fish. Judged by the photograph the snout has its anterior profile oblique instead of vertical.

Family Serranidae

Anthiasicus leptus Ginsburg

Anthiasicus leptus Ginsburg, Journ. Washington Acad. Sci. **42** (3): 91, photo. 1952 (off Alabama).

This species was described from a single specimen 108 mm in standard length, about 160 mm in total length, taken by the *Albatross* in 1885. A considerably larger specimen which appears to be the same species was obtained by the *Oregon* (U.S.N.M. 157788). The counts of this specimen which is 308 mm long, 240 mm in standard length, are as follows: D X 14. A III 8. P 18. Sc about 86. GR 10 + 27. These characters then agree closely with those of the holotype, and it apparently belongs to the same species. If so, this species undergoes a remarkable change with growth, as shown by the figures of the two specimens here published (Figs. 5, 6). The third dorsal spine and the second pelvic ray become greatly elongate and filamentous. Such growth changes are now and then duplicated in other serranids, although not often. On the other hand, in some instances such differences constitute specific or even generic characters. But the most remarkable growth change takes place in the shape of the caudal fin, from being deeply lunate to the unusual shape indicated on the drawing (Fig. 6).

Four specimens in the Chicago Natural History Museum, in intermediate sizes between the foregoing two specimens, lend some confirmation to the interpretation here given of growth changes in this species; but they do not complete the series to show a gradual transition.

In view of these probable growth changes, the validity of the genus *Anthiasicus*, having *leptus* for its type species, becomes doubtful, as its distinction from related genera was based to a large extent on differences that now appear to be governed by remarkable growth changes. Perhaps *Anthiasicus* should be merged with *Hemanthias* which is based on *peruanus*, a species from the Pacific coast of South America. However, only one specimen of the latter species, in indifferent condition, is available for comparison, and *Anthiasicus* is here tentatively recognized pending an adequate study of pertinent, comparative material.

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Reprinted from PACIFIC SCIENCE, *vol. VIII, no. 1, January, 1954*

Fishes Killed by the 1950 Eruption of Mauna Loa
I. The Origin and Nature of the Collections

W. A. GOSLINE, V. E. BROCK, H. L. MOORE,
and Y. YAMAGUCHI[1]

THE GREAT VOLCANO MAUNA LOA plays many parts in the Hawaiian community. We are here concerned with its role as a fish collecting apparatus. The present paper, which s the first of a series that will deal with the the fishes made available to us by the 1950 eruption, is limited to an account of the general nature of our collections.

The Mauna Loa lava flows of June, 1950, reached the sea on the Kona coast of the Island of Hawaii at three main points (Fig. 1). The first two of these flows dwindled to almost nothing a short time after entering the water on the morning of June 2. The third flow has far greater significance for us. It entered the ocean somewhat to the south of the other two (at 19°16′N., 155°55′W.) on the afternoon of the same day. Surges of lava from this flow continued to pass into the sea in quantity through June 4 and in lesser amounts through June 7.

Whenever a heavy surge of lava hit the sea, a large amount of steam rose from the surface (Fig. 2). Between the peaks of the surges, at least during the later stages of the flow, the moving column of lava entered the sea quietly, unexpectedly resembling an escalator disappearing through the floor of a department store (Fig. 3). Apparently the failure to cause surface steam at such times was due to the cooling and hardening of the outer layer of the lava column into a water-impervious shell through which the rest of the lava flowed. (Such conduits, now hollow and sometimes extending for distances of more than a mile, are well-known features of the Hawaiian terrestrial landscape.) Since the molten material flowed continuously without ever filling this shell, it can be assumed that the lava was breaking out somewhere below. Such outbreaks presumably produced steam explosions which could be felt even in a skiff anywhere near the flow. However, no steam from these assumed outbreaks ever reached the surface, nor was this to be expected unless they had been very large or very near the surface.

The total amount of lava entering the sea from the 1950 eruption was estimated by Macdonald and Finch (1950: 1) at over 100 million cubic yards.

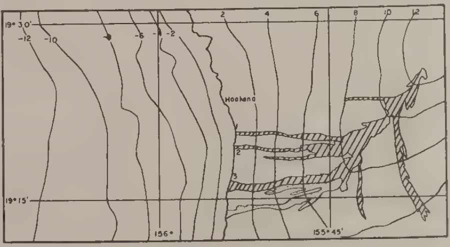

FIG. 1. Land areas covered by the Mauna Loa lava flows of 1919 and 1950. Heights above and below sea level given in thousands of feet. Diagonally hatched areas: 1950 flows; those that entered the sea are numbered in the sequence with which they reached sea level. Stippled area: 1919 flow. Redrafted in part from Macdonald and Finch.

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[1] University of Hawaii; Territory of Hawaii, Division of Fish and Game; U. S. Fish and Wildlife Service; and Territory of Hawaii, Division of Fish and Game, respectively. Manuscript received January 17, 1953.

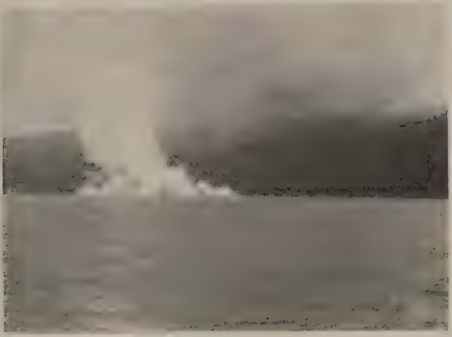

FIG. 2. Third lava flow reaching sea level on June 3.

Concerning sea conditions around the lava flow on June 2, Finch and Macdonald (1950: 6) state:

> By 5:00 P. M. a line of steaming water, marking the sub-sea course of the flow, extended to sea for about half a mile from the point where the . . . flow entered the ocean. Close to the shore and directly over the submerged flow, the water was boiling, and a semicircular area of hot turbulent water extended for a mile offshore. Many fish were killed and were seen drifting or were washed up on shore during succeeding days. The prevailing currents drifted the area of hot water southward.

On the morning of June 3 there was a "windrow" of dead fishes, 2 to 6 feet wide and extending as far as the eye could see, about 2 miles offshore from the flow. Inside this windrow, which marked a border between murky green and deep blue oceanic water, were other smaller, linearly arranged aggregations of dead fishes. At approximately half a mile from the point of entry of the lava, the water-cooled engine of the boat from which these observations were made became overheated.

By the afternoon of June 3 the windrows of fishes had broken up.

On June 6 the water in a roughly semicircular area several miles in radius around the point of entry of the lava was discolored and of dirty appearance. The relatively rare and scattered fish carcasses were found mostly toward the periphery of the disturbed area. Water a quarter of a mile from the flow was hardly warm, though a slick of upwelled hot water was still being formed closer in. The molten lava was still pouring into the sea continuously (Fig. 3), but in surges of greatly varying volume. The average width of the column entering the water at this time was perhaps about 30 feet.

On June 7 lava was entering the sea in greatly decreased volume and more or less intermittently, ceasing completely on this day or the next.

Four collections were made of the fishes brought to the surface of the sea by the 1950 lava flows. On the morning of June 2 Brock flew over the area where the lava was entering the water and made arrangements for collecting. In the afternoon of the same day Eugene Burke and Homer Hayes of the Territorial Division of Fish and Game took a small number of fishes. On June 3 the U. S. Fish and Wildlife Service vessel "Henry O'Malley," with Moore as scientist in charge, sent into the area a small boat from which collections were made in both the morning and afternoon. On the morning of June 6 Yamaguchi collected from a skiff. That afternoon Gosline, Homer Hayes, and Ed Keen took specimens from a sampan owned by Keen. On June 7 Hayes and Gosline returned to the area but found almost nothing.

Circumstantial evidence is rather strong that most of the fishes taken were brought to the surface during the early middle stages of the third flow. We know that the first stages of all three flows killed mostly inshore fishes, and we saw few of these. On the other hand, by June 6 relatively few fishes were coming to the surface, though live specimens were still occasionally seen. Furthermore, specimens in the June 6 collections often showed signs of more or less advanced decomposition.

Some of the fishes in these collections, particularly those taken on the first two dates, are in excellent condition. Others are not. Some of the latter were parboiled, some were partially decomposed, and some were both. The myctophids collected on June 6 gave the impression that if one looked at them in-ntly their scales would fall off. Neverthe- ss, the specimens in these four collections e probably in a better state of preservation an is most deep-water fish material.

Certain highly desirable data concerning ur collections are unobtainable. For one ing, little can definitely be said about the epth from which these fishes came. Some of ur specimens, such as the brotulids, are deep- ater bottom forms. Others like the mycto- hids are bathypelagic. A few probably ormally inhabit the surface layers of the open cean. A very few are obviously inshore forms hich had drifted into the area where we were ollecting. The maximum depth at which our shes were killed is likewise unknown. The ost that can be said is that the known depth records for such fishes as *Opisthoproctus*, of which we took five specimens, indicate that at least some of our material is from rather deep water, presumably greater than half a mile.

We also do not know how representative our collections are of the total fish fauna living in the area. Four types of selectivity have probably restricted the representativeness of our sample. Two of these are due to our collecting methods and can be taken into account. First, we made no effort to collect the obviously inshore forms. Second, small fishes were almost completely missed because we took only what we could see and catch with a dip net from a boat. The other possible selective factors are: differential decimation

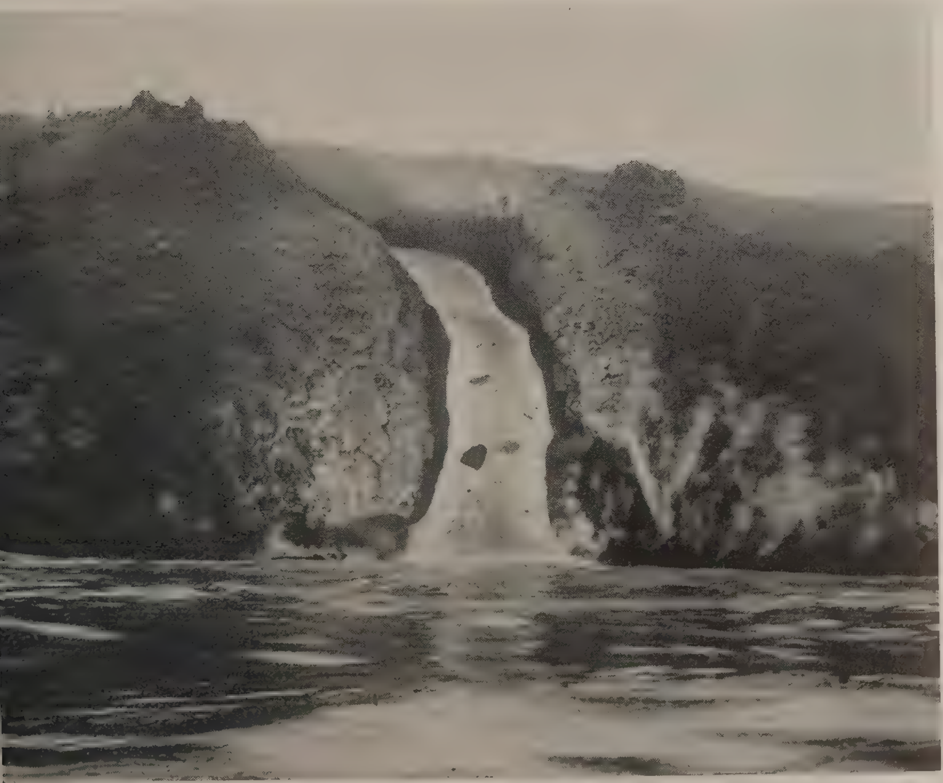

FIG. 3. The third lava flow entering the water several days later. Photograph by Jack Matsumoto.

among the species in the area and differential flotation among the species killed. These last two factors are impossible to evaluate, and the best that can be done is to point out their possible effects.

Death of these fishes may have been brought about by one or more of four causes: (1) the fishes may have been killed by simple overheating; (2) the lava entering the water may have introduced some directly or indirectly lethal chemical; (3) fishes with an air bladder may have been carried upward so rapidly by the upwelling water as to have caused overexpansion of this organ; and (4) the underwater explosions, caused by the breaking out of the molten lava from the conduits, may have caused some mortality. We do not have evidence that would make profitable a discussion of any of these possible causes of death. With any of them, however, it would seem likely that large fishes would be better able than smaller ones to move out of the way in time to avoid harm. The differential in decimation between large and small fishes may have been increased by the possibility that the water moving in to replace that which had upwelled carried with it small, weak swimmers from the surrounding region into the outbreak area.

Concerning the possibility of differential flotation, our only evidence is from the specimens we collected. With regard to these, two questions arise. What brought them to the surface, and, once there, why did they not sink back to the bottom? As to the first, one might suspect that the water heated by the lava would make its way through the water column above it to the surface, where it would spread out as a thin layer. Under such a hypothesis only the fishes from the area around the outbreaks would be brought to the top. Actually our collections contain epipelagic and a large number of bathypelagic fishes, as well as bottom forms. The presence of these pelagic species can best be explained by hypothesizing considerable mixing between the rising water and that around it. It does seem apparent that, regardless of the amount of mixing, fishes with a high specific gravity would be less readily transported to the surface than those with lighter bodies. Likewise, among fishes with the same specific gravity, those with a higher surface-volume ratio, e.g., small fishes, would be more easily carried in the upwelling water than those with a lower surface-volume ratio. It is possible, however, that not all the fishes we collected were originally brought to the surface by upwelled water, but rather that some of them were forced up after death by gases of decomposition.

This possibility leads into the question of why fishes were at the surface when we got there. Evidence from some of our specimens indicates that their air bladders became overexpanded and remained so after death, serving as floats. However, others show no expansion of an air bladder, and a large number of our specimens presumably do not even possess this organ. The presence of such fishes at the surface can best be explained by hypothesizing the formation of gases in parts of the body other than the air bladder. For example, the two brotulids we took on June 6 had the belly (but not the air bladder) greatly distended and empty. Most of our specimens, however, showed no abdominal distension. Whether decomposition gases and air bladder expansion can explain the presence of all our fishes at the surface seems open to question. Whatever the full explanation is, it must take into account the fact that, with the exception of two jellyfishes, we found no organisms other than fishes at the surface.

Our four collections together probably total 300 to 500 specimens distributed among more than 20 families. Perhaps a third of the individuals are myctophids. Except for the Myctophidae, and to a lesser extent the Sternoptychidae, none of the families is represented by more than a few specimens. Among groups unrepresented in our collections are sharks, flatfishes, and angler fishes.

In number of species our material would

em to be much richer than the number of dividuals might indicate. For example, each the five brotulid specimens represents a fferent species. Such a representation indi- tes the variety of fish life that must exist the deeper waters around Hawaii. Another ece of evidence bears on this same point. 1922 Jordan reported on seven species llected from the sea around the point of try of the 1919 lava flow (Fig. 1), six of hich he described as new. Of these seven ecies, at least three and probably six were ot taken by us.

There appear to be only two extensive re- orts on the deep-water fishes of the Central acific (Gilbert and Cramer, 1896; Gilbert, 905). Both of these are based on dredge auls made by the "Albatross" in Hawaiian aters. In the later paper, which summarizes e results, Gilbert recognizes 111 species aken below the 100-fathom line. Since 1905 ccasional deep-water forms, mostly taken y fishermen, have been added to the Ha- aiian fauna from time to time. The only revious paper based on Hawaiian fishes illed by a lava flow is that by Jordan (1922) entioned above.

After the "Albatross" material, the 1950 ava-flow collections constitute the most im- ortant deep-water fish material yet taken in he Central Pacific. Their value is enhanced y the fact that, though there is some overlap, he 1950 collections by no means duplicate hose taken by the "Albatross." For example, e took five species of brotulids whereas ilbert did not record any; conversely, in nother bottom-fish group—the flatfishes— ilbert reported 13 species and we did not ake any. Such examples, though extreme, gain indicate the tremendous size of the auna from which our samples were drawn.

It is planned to publish reports on the various groups in our collections in this journal as they are completed. The section on brotulids has been finished and appears elsewhere in this issue. Specimens of certain groups have been sent out to be worked up by others: the zeoids by Dr. George Myers, the myctophids and gonostomatids by Dr. R. L. Bolin, both of Stanford University, and the sternoptychids by Miss Janet Haig, of the Allan Hancock Foundation.

For constructive criticism and help in preparing the present paper we wish to thank Dr. R. L. Bolin, Dr. C. K. Wentworth, Mr. T. Cromwell, and various members of the University of Hawaii faculty.

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Reprinted from Transactions of the Nineteenth North American Wildlife Conference, March 8, 9, and 10, 1954. Published by the Wildlife Management Institute, Wire Building, Washington 5, D. C.

CONSERVING NEW ENGLAND HADDOCK

HERBERT W. GRAHAM[1]

U. S. Fish and Wildlife Service, Woods Hole, Massachusetts

The international mesh regulation for haddock fishing on Georges Bank went into effect June 1, 1953. The purpose of this paper is to report on the effects of this regulation during the first seven months of its operation. Conversion from small- to large-mesh gear took place gradually. A few boats converted soon after June 1, but conversion was not complete until October 1. From June 1 eight large trawlers were licensed to fish with small mesh in order to provide information necessary for testing the effect of the regulation. Observers were sent to sea on both large-mesh and small-mesh boats to sample the catches and to sample the fish discarded as well as those landed.

Until this regulation became effective, trawlers caught and discarded at sea millions of pounds of small haddock with nets having cod end meshes averaging 2⅞ inches (Herrington, 1935; Graham, 1952a, 1953b; Premetz, 1953). The regulation requires a minimum mesh size of 4½ inches inside dimension.

The purpose of this minimum mesh regulation is to increase the age of first capture of haddock, that is, to save the undersize fish for later capture at a larger size. An advantage is gained by saving young fish only if they grow sufficiently fast and if enough of them survive to be caught at a later date. Growth rates and total mortality rates are well known for Georges Bank haddock (Graham, 1952b). We calculated, using Beverton's (1952) formula, that with known growth and mortality rates and with present fishing effort, the optimum sustained yield would be obtained if the effort were applied to ages down to but not below three. Since there is a market for fish somewhat smaller than three-year-olds, fish of ages down to two and one-half years or slightly younger were regularly landed.

Accordingly the size of mesh in the cod end of nets was adjusted to allow escapement of fish two and one-half years of age and younger (Graham, 1952b). The lowest age of capture with the small-mesh cod ends had been one and one-half years. Again using Beverton's formula we calculated that increasing the lowest age of capture from one and one-half years to two and one-half years would increase the annual landings of haddock about 30 per cent after a new equilibrium had been attained if fishing effort remained the same. With the lowest age of capture the effort could be considerably increased without reducting the total yield. In fact, greater total yields would be expected with fishing intensity increased up to 25 per cent.

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[1] Director, Woods Hole Laboratory.

The immediate effect of the regulation was expected to be a slight decrease in landings due to a loss of a few small marketable fish. This decrease was expected to be less than 10 per cent the first year and to be compensated by benefits the second year. Thereafter there were to be increasing benefits until a maximum was attained several years later.

The results of the first few months of regulation have been more gratifying than expected. The small fish have been saved but the expected initial decrease in landings has not occurred. Instead there has been a definite benefit enjoyed by the large-mesh boats beginning from the time of conversion.

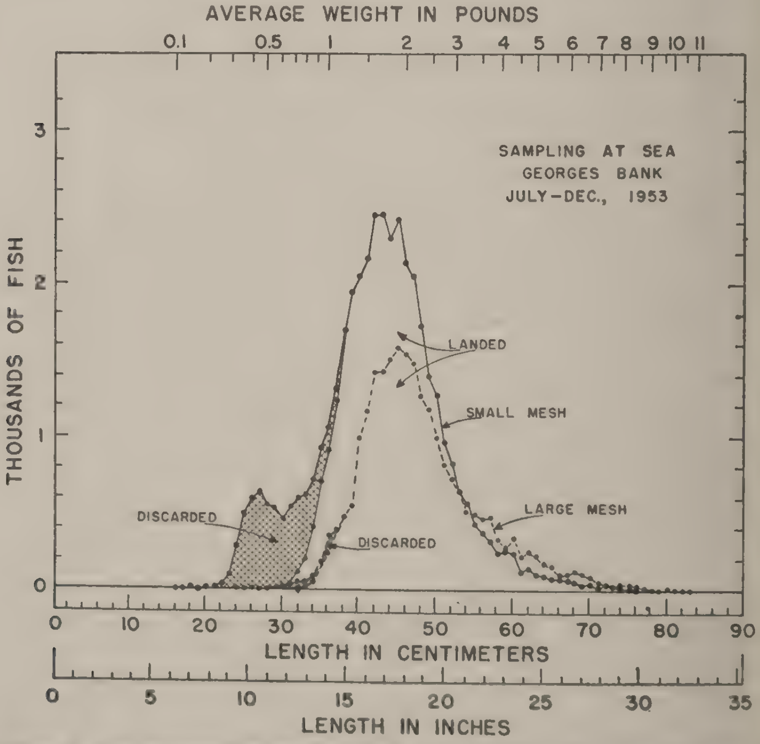
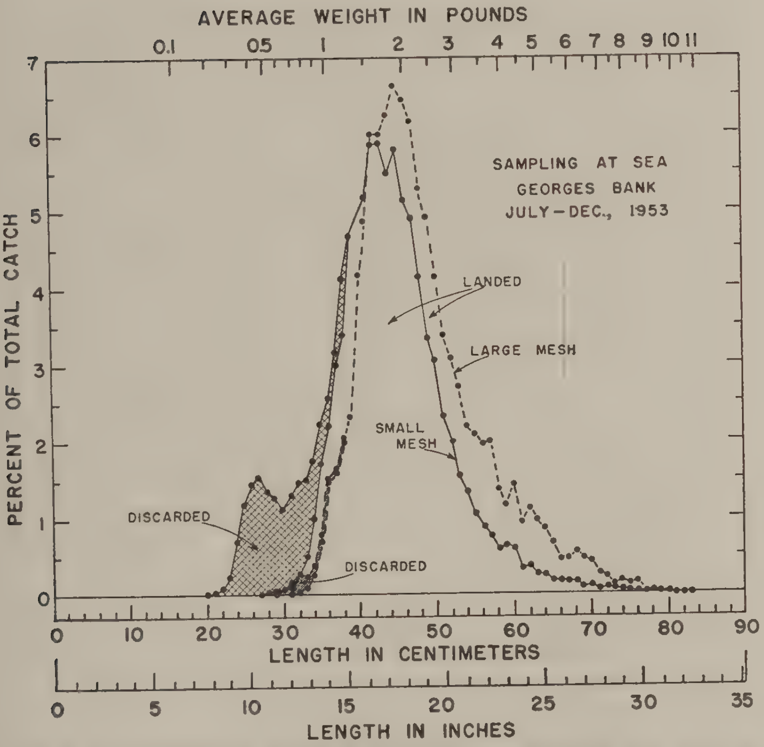


Figure 1. Size composition of Haddock catches on 14 observed trips during first seven months of regulations, June to Dec. 1953. Vertcal Scale: Thousands of Fish.



Figur 2. Size Composition of Haddock on 14 observed trips during first seven months of regulation, June to Dec. 1953. Vertical scale percent of total catch.

Figures 1 and 2 present a comparison of size distribution of fish caught by licensed small mesh vessels with that of fish caught by the large mesh vessel. It will be noted first that the quantity of discarded fish was reduced to a negligible amount by the use of the large mesh. Over two million haddock were saved by the use of these nets during the first half-year of the regulation and its use was not general for more than three months of that period. Another point demonstrated by these data is the lower landings of marketable fish under 40 cm. in length (2.5 pounds) by large mesh vessels. This loss, however, was more than compensated for by greater numbers of large fish caught and landed. Since these larger fish weigh more per individual, the net result was a benefit to the large-mesh boats.

The magnitude of this benefit is shown in Table 1. It will be noted that the average landings of haddock by the large-mesh boats during the last three months of 1953 were about 2,000 pounds per trip greater than that of the small-mesh boats. Other species of fish, such as cod and pollack, were also taken in greater quantity by the large-mesh boats. The total of all species landed by large-mesh boats was about 8,000 pounds greater per trip.

This direct comparison of landings of small-mesh boats and large-mesh boats for the same period is not a fair one because no account is taken of different sizes and efficiencies of the vessels represented. A more valid test is a comparison of each group's landings in the three months of 1953 with their respective landings in the same period in 1952. This comparison is also shown in Table 1. It will be noted that in the 1952 period the average catch per trip of haddock by the main part of the fleet, those boats which were subjected to regulation in 1953 (Group B), was less than the average catch per trip of the eight boats which in the 1953 period were licensed to continue fishing with the small mesh (Group A). Their total catch of all species, however, was slightly greater than that of the selected eight boats. Apparently the particular eight boats later selected for licensing normally tended to fish in areas in which haddock are proportionately more available than other groundfish.

In 1953, during the period of complete conversion of all regulated vessels, the catch of haddock from Georges Bank was down for all boats but to a greater degree for the licensed study boats. The total catch of all species held steady for the large-mesh vessels but went down 10 per cent for the licensed boats.

The landings of groundfish at Boston alone during the three month period amounted to about 33 million pounds, worth about three million dollars as landed. Had the regulation not been in effect, this

TABLE 1. COMPARISON OF LANDINGS OF SMALL MESH AND LARGE MESH VESSELS FROM GEORGES BANK

A. Average catch per trip[1] for period October, November, December, 1953

Group	Haddock Pounds	All Fish Pounds
Group A (8 Small Mesh Boats)	47,700	67,300
Group B (32 Large Mesh Boats)	49,600	75,500

B. Comparison of landings during October, November, December, 1952 with same period in 1953.

Group	Landings of Haddock Pounds per trip			Landings of All Fish Pounds per trip		
	1952	1953	% change	1952	1958	% change
Group A (8 boats)	60,900	47,700	−21.7	75,200	67,300	−10.5
Group B (32 boats)	54,800	49,600	− 9.5	75,400	75,500	+ 0.1

[1] The number of days fished per trip is fairly standard as the length of trip is subject to union regulation.

mount would have been about ten per cent less, or down by about 300,000, There is every indication that the advantage enjoyed by the arge-mesh vessels will continue throughout the year, when the benefit will be at the rate of $1,000,000 annually.[2]

What is the reason for these better landings? It was suggested when he regulation was proposed (Graham, 1952b, p. 30) that the new nets might prove more efficient and thus reduce any deleterious initial ffect caused by the loss of some small marketable fish. Experiments by Davis (1934) in England had indicated greater catches of the arger sizes of haddock with a three-inch mesh than with a two and one-half inch mesh.

When the advantage of the larger mesh in the Boston fleet was first noted, it was suggested that perhaps the fishermen had changed their fishing practices. Colton (unpublished manuscript) has found that there is to some extent a separation of sizes of haddock with depth on Georges Bank. At certain seasons of the year, at least, larger haddock are found in depths greater than 90 fathoms, and the actual pounds of haddock available per tow are greater there than in depths less than 60 fathoms.

If fishermen should tend to fish deeper in order to avoid concentrations of small fish because of a loss of some of the smaller sizes, they would obtain larger catches by dragging in the areas of larger fish. However, our present analysis of the distribution of fishing effort with depth does not reveal any difference in the habits of the large- and small-mesh boats. The study boats during the last three months of 1953 spent as much of their time proportionately in depths over 90 fathoms as did the large-mesh boats. We are forced to conclude for the present, at least, that the comparatively greater landings of the large-mesh boats is due to greater efficiency of the large-mesh nets.

The effect of the conservation of the young fish will, of course, not be evident for a year or two. This advantage will be added to that resulting from the more efficient net. The increased catch of the larger fish will not negate the value of conserving the small fish. Increasing the efficiency of the net constitutes an increase in the fishing effort, and, as stated above, increasing the effort up to 25 per cent will result in increased total sustained yield.

Thus the large-mesh net seems to be operating with a double advantage: small fish are being saved to add to the catch later at the same time that catches of larger fish are being immediately increased.

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[2] This is assuming that the net has the same beneficial effect on Nova Scotian banks as has been calculated for Georges Bank. A large proportion of the effort of the Boston fleet is now spent on Nova Scotian banks.

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DISCUSSION

DISCUSSION LEADER WALLACE: The question of mesh size and what it will do has always been an important issue, and I think he has demonstrated how valuable it can be when the change in mesh size is based upon a series of careful research studies.

MR. CHARLES E. JACKSON (National Fisheries Institute, Inc., Washington, D. C.): I want to ask Dr. Graham if the fishing time is the same with the regulated as compared with the non-regulated mesh. In other words, was there any more time put in trawling with the large mesh than the small mesh, in your figures?

DR. GRAHAM: The figures I showed gave pounds landed per trip, and a trip is rather a standard length of time. The length of the trip is regulated by the union regulations—about 8 days—so we consider that as a very good measure.

We heard some reports that the skippers were reducing the revolutions of the engines when they were using the large mesh. We thought perhaps that offered less resistance, and the captains wanted to trawl at the old speed, but we don't have enough information on that to make any statements. The boats may be traveling a little faster.

The large mesh saves some time for the fisherman because he doesn't have to cull. What he doesn't want has already gone through the net. With the small mesh they had to spend a lot of time culling out the small fish. That does not increase the number of tows, because with fishing the way it is now, they always get the deck cleaned up before the next tow comes in, anyway.

It simply means the fishermen have more time to relax and play cards or whatever they do. The number of tows per trip is the same.

MR. WALLACE: Dr. Graham, I believe you computed that, theoretically, it would take same period of time before there would be an increase in the catch by the 4¼" gears. How do you account for the fact that in the first six months there was this very pronounced improvement in the fishing with the 4½" gears, even though the fish had not had a chance to grow?

DR. GRAHAM: That is due entirely to the increased catch of large fish, which are caught both by the large and the small mesh, and will be added to the effect of the conservation of the small fish. We can't expect to get the benefit from the conservation of the small fish for a few years.

As I said before, this was not completely unexpected. Davis, in England, in 1934, conducted some experiments on different sized meshes, and found the larger mesh to be more efficient in trawlers, catching more pounds of fish per tow than a small mesh net. It is hard to visualize. You think the net doesn't offer very much resistance to the water, but moving pictures under water show that there is a terrific strain on the meshes of the net when they are open.

Of course, we are quite gratified by these results, even though we didn't predict is large change, because it was quite a battle getting this regulation through. have been in it only three years. The battle started years ago, and it was going ick and heavy when I entered the picture.

First of all, the fishermen said it wouldn't do any good to use the large mesh ecause the mesh would fold together anyway, and that you couldn't conserve at way. We finally got them convinced that it would do some good, using ritish underwater films, among other things. Then when the regulation be-ame a definite thing, and they realized they were going to have to use the rge mesh, they said: "We can't possibly make a living fishing with a large esh like that." When they actually saw the large size they would have to se, they were aghast. They said, "This won't hold any fish at all. They'll all et through."

After the regulation was put into effect, they made very strong representations o cancel the whole thing. There were many times when we thought the project ould soon collapse, but it is in effect now, is being enforced and the fishermen ke it.

At present they are not quite sure whether to believe us or not. They don't ccept figures like this just because somebody presents them to them in black nd white. Right now I think they are in a transition period where they are eginning to realize they are better off with the large mesh, so it may be difficult o get volunteers to use the small to prove our point conclusively.

Right now we are not having any trouble, and I think everyone is happy as far s conservation is concerned. There are economic problems connected with this shing that I am not going to discuss today.

Dr. Smith: My experience with commercial fishermen is that anything that akes it easier is all right with them. Now, when they had this big mesh—a few f them, a few years previously—why didn't these fishermen notice the same esults which they have now noticed as a result of regulation, since it is easier o handle them on deck and so on? Why didn't they stay with it?

Dr. Graham: In the first place, it's not easy to see this effect. Fishermen don't eep records too well, and you have to compare this year's catch with last year's. f the regulation goes into effect when there is a strong year class passing out of he picture, and the abundance is dropping and they try something experimentally hat way, they will blame it on the net, just as during the summer and early all, everything was blamed on the large mesh, so you can hardly expect the ishermen to realize that they are better off with the large mesh.

As a matter of fact, they were using too light a twine, so they were getting ear-ups. If you break one mesh in the large mesh net, it leaves quite a hole; f you break one in the small mesh, it doesn't matter so much. I think that is robably one reason they kept using smaller meshes. We increased the weight f twine, using one almost lkie a piece of quarter-inch rope, made out of manila, ery heavy and durable. It lasts just as long as the small mesh.

Another difficulty arose from the fact that you couldn't get complete coopera-ion in the industry. Fishermen are individualists. Perhaps one of them wouldn't o along with the idea, and one day he might bring in a larger catch, then the ther would feel, "Well, this is getting us nowhere," and they would all go back o the small-mesh net.

RELATIONSHIP OF LENGTH OF FISH TO CIDENCE OF SEA LAMPREY SCARS ON HITE SUCKERS, *CATOSTOMUS COMMER-NI*, IN LAKE HURON.—During the course of perimental fishing operations conducted by the aff of the Hammond Bay Fishery Laboratory (a eld station of Great Lakes Fishery Investigations) 1950–51, length measurements and records of arring incidence and number of scars per indidual were obtained for a sample of 552 white ckers, *Catostomus commersoni* (Lacépède). The sh were captured during the period February 26 April 16, 1951, in trap nets of which all but one were of conventional Great Lakes design. The exception was an experimental type, of substantially smaller dimensions than the conventional nets and with 1-inch mesh, extension measure, in the pot. In the standard net the mesh size in the pot was 3 inches. Although the entire sample came from nets fished under the ice in 10 to 20 feet of water in Duncan Bay on the eastern edge of Cheboygan, Michigan, we believe, on the basis of our other fishing operations, that these fish are reasonably representative of the white sucker population of the general area.

TABLE I

ELATIONSHIP OF LENGTH OF WHITE SUCKERS TO INCIDENCE OF SCARRING BY SEA LAMPREYS AND DISTRIBUTION OF SCARRED FISH ACCORDING TO NUMBER OF SCARS PER INDIVIDUAL

Total length (inches)	Total number of fish	Number of fish scarred	Percentage scarred	Number of scars				
				1	2	3	4	5
5.0–5.9	8	1	12.5	1	...	...	...	...
6.0–6.9	25	2	8.0	2	...	...	...	...
7.0–7.9	15	...	0.0	...	...	...	...	...
8.0–8.9	10	1	10.0	1	...	...	...	...
9.0–9.9	23	2	8.7	2	...	...	...	...
10.0–10.9	55	9	16.4	9	...	...	...	...
11.0–11.9	114	30	26.3	27	3	...	...	...
12.0–12.9	138	55	39.9	46	7	2	...	...
13.0–13.9	82	38	46.3	29	9	...	...	...
14.0–14.9	48	30	62.5	22	5	1	2	...
15.0–15.9	15	10	66.7	5	5	...	...	...
16.0–16.9	7	5	71.4	3	1	...	...	1
17.0–17.9	7	5	71.4	3	1	1	...	...
18.0–18.9	1	...	0.0	...	...	...	...	...
19.0–19.9	3	3	100.0	...	3	...	..	...
20.0–20.9	1	1	100.0	...	...	1	...	...
otal number ..	552	192	34.8[1]	150	34	5	2	1
verage length..	11.9	13.1	...	12.7	14.2	15.0	14.0	16.0

[1] Grand average percentage of scarring.

LENGTH IN RELATION TO PERCENTAGE OF SCARRING.—The upward trend in the percentage of white suckers bearing sea lamprey scars with increase in the length of the fish is readily apparent (Table I and Fig. 1). At lengths below 11 inches the percentages were consistently small—nil to 16.4. Scarring incidence rose above 25 percent at 11.0–11.9 inches (26.3 percent scarred), passed the 50-

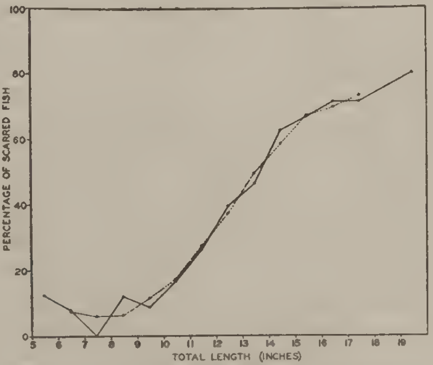

Fig. 1. Regression of scarring incidence on total length of white suckers in northern Lake Huron, 1951. The solid line represents the percentages as given in Table I (except that the data for the 5 largest fish were combined to obtain the percentage of 80 for the length range 18.0–20.9 inches). The broken line shows the same data, smoothed by a running average of three.

percent level at 14.0–14.9 inches (62.5 percent scarred), and continued to increase to 71.4 percent at 16.0–17.9 inches. Among the 5 largest suckers 4, or 80 percent, had suffered attacks from sea lampreys (this figure of 80 percent was plotted in Fig. 1 as representative of fish over the length range 18.0–20.9 inches).

This trend is brought out even more sharply by the condensed data of Table II. Here it may be seen that the scarring incidence was 11.0 percent for white suckers less than 11 inches long, 40.1 percent at 11.0–14.9 inches, and 70.6 percent at 15.0–20.9 inches.

Despite numerous irregularities, to be attributed largely to small numbers of fish at certain lengths, the curve of regression of scarring incidence on length of fish (Fig. 1, solid line) shows a distinct tendency to be sigmoid. This characteristic of the regression is brought out more clearly when the original percentages are smoothed by a running average of three (broken line). In the computation of the percentage for the last point on the smoothed curve, the value of 80 percent for suckers over the length range 18.0–20.9 inches was given a weight of only 0.5 as compared with weights of 1.0 for the percentages at 16.0–16.9 and 17.0–17.9 inches.

The following factors are believed to have contributed to the observed increase in the incidence of sea lamprey scars with increase in the length of white suckers: mechanical difficulties of attachment of a sea lamprey to a small fish; increase, with increase in length of white suckers, in the probability of surviving a sea lamprey attack; the greater length of time the larger (and presumably older) suckers had been exposed to the danger of attack.

Inasmuch as we are without good information from which to judge the relative importance of the factors listed above, any further discussion of them would be little to the point.

LENGTH IN RELATION TO NUMBER OF SCARS.—Of the 15 white suckers less than 11 inches long that had suffered sea lamprey attacks, all bore a single scar (Tables I and II). At all lengths above 11 inches, however, some fish carried more than one scar (the single fish at 18.0–18.9 inches had not been attacked). In the entire sample, 150 white suckers had suffered a single sea lamprey attack, 34 had been attacked two times, 5 three times, 2 four times, and 1 five times.

TABLE II

PERCENTAGE OF SCARRED WHITE SUCKERS AND INCIDENCE OF SINGLE AND MULTIPLE SCARS FOR THREE INTERVALS OF LENGTH

Item	Total length (inches)			Total or Average	Average length
	5.0–10.9	11.0–14.9	15.0–20.9		
Total number of fish	136	382	34	552	11.9
Number of fish scarred	15	153	24	192	13.1
Percentage scarred	11.0	40.1	70.6	34.8	...
Fish with single scars					
Number	15	124	11	150	12.7
Percentage of all fish	11.0	32.5	32.4	27.2	...
Percentage of scarred fish	100.0	81.0	45.8	78.1	...
Fish with multiple scars					
Number	...	29	13	42	14.3
Percentage of all fish	...	7.6	38.2	7.6	...
Percentage of scarred fish	...	19.0	54.2	21.9	...

The incidence of multiple scarring tended strongly to increase with increase in the length of the fish. As was stated above, only single scars were observed at lengths below 11 inches. Over the range 11.0–14.9 inches, 19.0 percent of the marked fish had experienced two or more attacks, and at 15.0–20.9 inches 54.2 percent of the marked suckers exhibited multiple scarring. This same trend is apparent from the following record of the number of sea lamprey marks per scarred individual at different lengths: 5.0–10.9 inches, 1.00; 11.0–14.9 inches, 1.52; 15.0–20.9 inches, 1.75.

The same factors listed in the preceding section in explanation of the regression of scarring incidence on length of fish (without reference to number of scars) no doubt contributed to the observed relationship between fish length and the occurrence of multiple scars.

CONCLUSION.—If information on the incidence of sea lamprey scars on white suckers in northern Lake Huron is to be used to judge the relative abundance of sea lampreys and the damages inflicted by that parasite on the sucker stock, data must include records of the lengths of fish. It is to be suspected strongly that a similar conclusion applies in other localities and to other species preyed upon by the sea lamprey.—A. E. HALL, JR., AND OLIVER R. ELLIOTT, *U. S. Department of the Interior, Fish and Wildlife Service, Rogers City, Michigan.*

CHANGING CONCEPTS IN FISHERY RESEARCH ON THE GREAT LAKES

By

RALPH HILE

Fish and Wildlife Service, Ann Arbor, Michigan

REPRINTED FROM
PROCEEDINGS
OF THE

GULF AND CARIBBEAN FISHERIES INSTITUTE

SIXTH ANNUAL SESSION

MIAMI BEACH NOVEMBER, 1953

Changing Concepts In Fishery Research On the Great Lakes

RALPH HILE

Fish and Wildlife Service, Ann Arbor, Michigan

It must seem illogical to approach the subject of accomplishments of fishery biology on the Great Lakes by detailing certain weaknesses of earlier researchers and points of view. Yet the paradox may not be as grievous as would appear. Surely we may count it an accomplishment to have become aware of defects both in our way of doing and of thinking and to have made a start toward the development of new lines of attack which we feel will make our future efforts more productive.

Before undertaking the painful specification of past shortcomings, let us digress momentarily to give a minimal background on the Great Lakes and their fisheries.[1] The five lakes have a combined surface area of 95,000 square miles—61,000 within U. S. boundaries and 34,000 under Canadian jurisdiction. The U. S. waters of the Great Lakes are shared among eight states, each of which has full jurisdiction over the fisheries within its boundaries. Thus we have altogether nine fishery codes.

Ecological conditions vary widely both between and within lakes — often in contiguous waters. We know, for example, that within the relatively limited confines of an area as small as Green Bay — only 118 miles long and at most 23 miles wide — the life histories of certain shallow-water species differ greatly between the northern and southern ends. It is these highly variable shallow waters that are most productive. This same Green Bay, for example, has contributed 60 to 70 per cent of Lake Michigan's total production in recent years. Only the deeper waters of the three upper lakes and Lake Ontario offer anything even approaching the degree of uniformity and stability of habitat encountered in the open sea.

Commercial production of fish in the Great Lakes is relatively small — characteristically 70 to 80 million pounds in U. S. waters in recent decades — but is economically important. As an illustration, the dollar value of Great Lakes production equalled that of the Pacific sardine when that fishery was at its height. The lakes are without large fishing ports; the catches are landed at hundreds of points scattered along the nearly 5,000 miles of U. S. shoreline.

Principal gears are gill nets (almost always fished on the bottom and never drifted) and various types of impounding nets. Most fisheries are composite, in that several species are taken simultaneously and most species are taken in

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[1] For accounts of the Great Lakes fisheries at various periods see: Milner (1874); Smith and Snell (1891); Rathbun and Wakeham (1897); Koelz (1926). Gallagher and Van Oosten (1943) gave considerable historical information on the fisheries, offered detailed discussions of problems of regulation, and published all available records of production through 1940. Van Oosten (1938) wrote a historical sketch with special references to State of Michigan waters.

REPRINTED FROM THE PROCEEDINGS OF THE GULF & CARIBBEAN
FISHERIES INSTITUTE, 6TH ANNUAL SESSION, SEPTEMBER, 1954.
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quantity by several kinds of gear; this circumstance has forced the development of special procedures for the estimation of availability and fishing pressure.[2]

The complexity of situation indicated by these sketchy comments played an important role in the framing of past biological investigations of the Fish and Wildlife Service and inevitably must loom large in the development of future research plans. Confronted by scanty and fluctuating budgets the Service took the only approach really open — studies of individual commercially important species and fisheries based on them in single lakes or sections of lakes. Even here the selection was more by circumstance than by plan, for materials were collected as opportunity presented itself during the course of practical studies — mostly on gear selectivity[3] — of sufficient urgency to attract outside support from State and other agencies.

This haphazard approach was not as unproductive as might have been anticipated. Numerous sound, and a few substantial, pieces of work were completed and a large amount of fundamental information was accumulated. Yet we are in the anomalous situation of the property owner who has considerable building material scattered about his lot—has even made a start on construction—but still is living in a tent.[4]

It is to be suspected also that the necessity of placing first one fish and then another under our scientific scrutiny may have betrayed us into oversimplification of the problem of productivity. The typical history of production in the Great Lakes has included an initial period of relatively high output dominated by first-choice species as lake trout and whitefish, followed by a progressive deterioration in which the production of the valuable species declined and less and less desirable varieties as freshwater drum, suckers, and carp became more prominent in the catch. At times this deterioration reaches the point that total production is controlled by the market for "rough" fish.

The sequence—reduced production of one after another choice species followed by increased take of less desirable varieties—was given the interpretation both common and generally acceptable at the time. It was depletion through overfishing in the simplest classical sense—removal of the stock at a rate faster than it could replace itself. First one species or group of species was depleted; then the fishermen turned to another and the process was repeated until, as a result of the successive, largely independent declines, the cupboard was bare except for the neglected varieties of lowest quality.

Now, none of us engaged in the earlier research on the Great Lakes is so poor a biologist as to believe that different species of fish do not affect each other. Yet the conviction that the importance of these interactions among species was negligible in comparison with the direct depleting effects of unwise fishing was implicit, if not always stated, in the pronouncements of the period. Warnings as to the impending collapse of the fisheries stressed always the growing scarcity of individual species through the simple nechanics of too rapid removal. The mere fact of declining take came o be accepted as *prima facie* evidence of overfishing to be corrected only hrough restrictions.

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[2] For descriptions of procedures employed for the analysis of Great Lakes fishery statistics see: Hile (1937); Hile and Jobes (1941); Van Oosten, Hile, and Jobes (1946).

[3] Van Oosten (1932, 1933, and 1935) described and gave summaries of findings for some of these pioneering studies of savings gear.

[4] See Hile (1952a) for a historical review of Federal research on the Great Lakes fisheries.

The regulatory measures recommended were designed to correct a simple nbalance between rate of recruitment and rate of exploitation—reduction f fishing intensity through higher size limits, closed seasons and grounds, estrictive specifications on gear (principally in the form of larger meshes). iven sufficiently drastic restrictions, it was argued, the fishery surely could e saved from almost certain doom, and most probably much of its former productivity restored.

We arrive now at the matter of changing concepts. Briefly stated, the accumulation of new information and the re-appraisal of old are forcing on us the realization that the cause of deteriorated fisheries in the Great Lakes, and hence the means for their improvement, do not offer a problem as simple as has been supposed. It is not suggested that over-fishing in the strict sense has not taken place, or that regulations past and present have been useless. As recently as the early and middle 1930's we saw the destruction of stocks of whitefish in Lake Huron that almost surely could have been prevented or lessened by the adoption of relatively simple restrictions (Van Oosten, Hile, and Jobes 1946), and bad as conditions are now they might be far worse in some fisheries but for restrictive measures in effect. On the other hand, we do know that the imposition of restrictions has not been generally effective in restoring productivity and that on occasion overzealous protection has all but put an end to potentially productive fisheries.[5]

Our principal departure from earlier thought concerns not so much the cause of the deterioration of the fisheries as the process whereby the change has come about. Although we concede readily the importance of such factors as the deposition at various periods of sawdust, bark, and silt, the pollution from varied industrial and domestic wastes, the fertilizing effects of sewage effluents and drainage from agricultural lands, and disruptions from introductions of exotic species of fish, we must still consider fishing activity a principal cause of the decline of the fisheries. There is a good reason to suspect, however, that in the mixed stocks of our shallow-water areas, ". . . a major effect of fishing lies in the disturbance of ecological relations among the fishes. Thus, fishing pressure to which the species are subject in common may give one a competitive advantage and place another at a disadvantage. Differences of fecundity, growth, and longevity, . . . that lead to a particular species composition at one level of intensity may bring about a greatly different composition at another. Changes of this origin can be accentuated if fishing pressures, relative to the actual stock, differ from species to species. Furthermore, the generally lower level of commercial production in the modern period suggests the possibility that fishing pressure on commercially exploited species may have operated so much to the advantage of the smaller, non-commercial species that the latter now make up an increased percentage of the total biological production."[6] In brief, we hold that fishermen did not turn from declining first-choice fish to exploitation of a pre-existing stock of cheaper fish but rather that through ecological changes the poorer fish became more plentiful as the better ones grew scarce. We question whether the biological production of fish ever has declined significantly in the Great Lakes; on the contrary the fertility of the lakes probably has increased with the rise of human population.

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[5] A good illustration of this point is provided by studies still in progress on the yellow perch of southern Green Bay (Hile 1953). Here, the evidence indicated that production was limited by the inability of most individuals in the slowly growing stock to survive the more than five years required to attain the minimum legal length of eight inches. The effects of a reduction of the size limit to 7½ inches are now being studied.

[6] From Hile, Lunger, and Buettner (1953).

Although the general increase in the percentage of cheaper fish in the commercial take leaves little doubt that fishing has been on the whole prejudicial to the welfare of first-choice varieties, certain outstanding exceptions preclude the assumption that we have a simple case of selective fishing against the better species. In some areas the changes in ecological conditions seem to have operated for the betterment, not to the detriment, of first-choice fish. A striking example comes from the Michigan waters of Green Bay where the 1929-1949 average annual production of whitefish, a high-priced species always in market demand and fished intensively, was 4½ times the average take in the early fishery of 1891-1908 (Hile, Lunger, and Buettner 1953). Similarly, in Lake Erie the catch of the highly prized walleye, fished intensively without benefit of a closed season during spawning and at a size limit a full two inches below that recommended 20 years ago, has shown a strong upward trend of production during nearly all of these same 20 years—a trend that has carried the take to unprecedented high levels.[7]

Thus, our problem is complex indeed. It is one that calls for study of populations of fish rather than of individual species. We need most to understand interactions among species and how they are affected by changing environmental conditions. In this situation we see little prospect for an approach toward sounder management for higher productivity through the application of fishing theory as developed among others by Baranov, Russell, Graham, and Beverton in Europe, by Thompson, Ricker, and Schaefer in North America, and as applied so brilliantly by some of them toward the solution of fishery problems. This is not to imply that our particular fish are exempt from the laws of nature—that rates of growth, natural mortality, recruitment, and exploitation are not primary determinants of yield. Rather, these factors do not behave in our fish stocks in a fashion which must be assumed in a model population if one is to arrive at equations for which there is any chance of obtaining even approximate solutions. True, fishing theory has grown to accept the idea of a certain fluctuation of rates other than rates of exploitation, has recognized possible interactions among these rates, and to some extent has made adjustments for them. Also, the importance of hydrographic and other environmental conditions in the determination of abundance has long been generally recognized. Nevertheless, the validity of mean rates—perhaps more properly typical rates—and the concept of factors operating within a largely independent, self-contained stock is implicit in and essential to the theory.

Our stocks of fish in the Great Lakes clearly do not meet the conditions hat must hold if fishing theory is to be the basis of management.[8] Not nly do we have constantly growing evidence that extrinsic factors by far vershadow intrinsic factors in the determination of availability of a particular tock; it is apparent also that in some stocks the fluctuations are of such a agnitude as to make management on the basis of mean or typical rates ut of the question. Time does not permit a detailing of evidence in support f these statements. From historical records we do know that species once lentiful are now scarce and species once scarce are now dominant.[9] During he periods of our own researches we have seen enormous and sudden changes f availability and species composition which, though they may possibly e related to previous fishing activities are not to be explained sensibly, t least in quantitative terms, by any theory as yet formulated.[10] Although e have used and propose to use the most exacting analytical procedures vailable to us and within our capabilities, our central problem is not one f vital statistics. Rather, it is a problem of biological understanding. We ust learn the causes of or at least the conditions that permit or accompany he great fluctuations that occur; we must understand better how fluctuations f one species affect another; we must learn more of the role of meteorological nd hydrographic factors; and, of course, even though the application may ot be by equation and formula, we must study carefully the effects of ishing.

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[7] Gallagher and Van Oosten (1943) considered the 1885-1908 average annual production of 1,949,000 pounds of walleyes to be the "normal" take for U. S. waters of Lake Erie. After the catch declined and averaged only 1,418 pounds or 73 per cent of normal in 1912-1935. How sharply the trend has been upward during the last 20 years is demonstrated by the following 5-year averages: 1933-1937—2,001,000 pounds; 1938-1942—3,531,000 pounds; 1943-1947—4,434,000 pounds; 1948-1952—5,126,000 pounds.

In situations as intricate as those in most of our Great Lakes fisheries, we must approach understanding through a series of approximations. Precision in our statements relative to changes in populations will come slowly. We count it unlikely that in our time we shall be in position to recommend changes of management procedures with full confidence as to the extent or even the direction of their effects. We expect nevertheless to recommend changes of regulation which, according to our best knowledge, give promise of being beneficial and to check carefully to determine their actual effects. Improvements in the regulation and management of the Great Lakes fisheries long must come through experimentation rather than deduction. The function of the biologist will be that of furthering maximum efficiency in this experimental process.[11]

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[8] But for the fact that the stocks of lake trout have all but disappeared from Lake Huron and Lake Michigan and are dwindling so rapidly in Lake Superior that early collapse of the fishery threatens (Lakes Ontario and Erie have never been important centers of lake trout production), we should need to make a possible exception for that species. Ecological conditions in the deeper waters inhabited by the lake trout are far simpler and more stable than those in the shallower areas. Here the lake trout has existed as the principal predator on large stocks of small species of coregonids (ciscoes or chubs) and of cottids and sticklebacks. The only other species of similar predatory habits (and one equally vulnerable to the sea lamprey), the burbot, has been much less abundant. This relatively steady environment and simplicity of interspecies relationships, together with the long life of the lake trout and the normal dependence of the fishery on a considerable range of age groups, led to a high degree of stability. Although the production and availability of lake trout have exhibited both long-term and cyclic trends (Hile 1949; Hile, Eschmeyer, and Lunger 1951a, b), the fishery has in general lacked the sudden, wide fluctuations characteristic of the fisheries for so many Great Lakes species. Despite the fact that the point has not been tested, we suspect that the application of fishing theory to the lake trout fishery would have been profitable.

[9] Smith and Snell's (1891) comprehensive port-by-port account of the Great Lakes fisheries in 1885 makes possible many instructive comparisons of early with present-day conditions. Valuable also are their descriptions of changes in species composition that had recently occurred or were taking place at the time of their survey. Their following comment (p. 116) on the fishery of Oconto County, Wisconsin, for example, gives evidence that the present strong dominance of the yellow perch in southern Green Bay was in the process of establishment in the 1880's: "While the whitefish and the pike have been disappearing the perch have become enormously more abundant. Before 1882 only a few scattered ones were obtained, averaging about six to each lift of the pound net. Since then they have become more and more numerous each year, until in the spring of 1885 never less than 50 pounds and sometimes as much as a ton of them were taken at a lift."

[10] A recent example of these tremendous fluctuations is provided by the 1943 year classes of three species in northern Green Bay, Lake Michigan (Hile 1950; Hile, Lunger, and Buettner 1953) so strong as to lead to a modern high in the production of lake herring and to all-time records in the output of whitefish and walleyes. Although the analysis of data on the walleye remains to be completed, the preliminary estimate that the contribution of the 1943 year class to the commercial fishery will be 50 to 60 times the average of year classes for the preceding 10-15 years is in no way excessive.

The principal accomplishment of fishery biology in the Great Lakes, then, has been to teach us that for more effective understanding we must focus our attention on how fish live together in a constantly changing environment. Circumstances may require that we study species individually, and we may never achieve the goal of simultaneous research on every variety in a population; but we must never think in terms of one species alone, for it does not live alone.

This statement of changing outlook carries no admission that our past efforts have been futile: rather it is an expression of hope that our future programs will be more effective. We envision no great change in our methods of research. We shall continue to count and measure fish, read scales, examine stomachs, analyze statistics of production, intensity, and catch per unit effort. We trust only that we can schedule our operations more sensibly and piece together our information to form a more comprehensible picture.

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OPENING REMARKS OF THE PRESIDENT

STATUS AND FUTURE OF THE AMERICAN FISHERIES SOCIETY

Ralph Hile

I can think of no more fitting theme for the opening remarks of this, our Eighty-third Annual Meeting, than an appraisal of the status of our organization and comments on the means whereby that status may be improved for our common benefit.

During the past year or so criticism of the American Fisheries Society has been much in vogue. To a large extent the criticism has been healthy in that the critics focused attention on certain weaknesses in our structure and function, proposed methods for their elimination, and offered assistance in bringing about improvement. This attitude speaks well for the future of our organization. It demonstrates an interested membership—a membership that senses the possibilities of our Society and is determined to see them realized. Without alert and active members no organization can hope to progress.

Do not misunderstand me—not all criticism has been healthy or helpful. We have heard also the raucous voices of the generalized complainers—those spiritual hypochondriacs who seek no goal but are merely fascinated by the melody of their own flatulence. I should not trouble to mention this insignificant minority did I not feel that even they can be redeemed. To those few that are tempted to seek progress by urging others to work harder and improve their ways may I offer the observation that payment of dues does not carry with it a grandstand seat and the privileges traditionally appurtenant thereto; rather, it makes you one of a team—a team that needs your help and will succeed or fail according to the way its members play the game.

Despite a sprinkling of chronic malcontents all indications point toward a new and better era in our Society's affairs. Our membership is at a record level, our finances are sound, and, what is more important, we find a heightened interest in our organization's activities. To the end that this newly found energy may be gainfully applied and not be dissipated futilely it is well for us to inquire into our structure and into our program.

One immediate problem concerns changes in our constitutional organization and procedures that may promote efficient operation and make for a wider participation of members in the Society's affairs. Such questions as these occur. Should officers be elected by a general ballot distributed to all members? Should procedures for the amendment of the Constitution be simplified? (Here I may mention that one of the two procedures now available has proved impractical and the other rather cumbersome.) Have some of our Standing Committees outlived their usefulness so far that they should be discontinued? Do we need new Standing Committees designed to meet new needs of the Society? Should our Executive Committee—which now numbers 17 members and increases as new Regional Divisions

Reprinted from Volume 83 (1953), Transactions of the American Fisheries Society.
Published 1954. Printed in U.S.A.

NOTES ON THE PREDATION OF THE HARD CLAM, *VENUS MERCENARIA*, BY THE MUD CRAB, *NEOPANOPE TEXANA*

By

WARREN S. LANDERS

Reprinted from *Ecology*, Vol. 35, No. 3, July, 1954

NOTES ON THE PREDATION OF THE HARD CLAM, *VENUS MERCENARIA*, BY THE MUD CRAB, *NEOPANOPE TEXANA*

The predatory nature of the common mud crabs with respect to oyster populations in Delaware Bay has been recognized and noted (McDermott and Flower 1952). However, to the author's knowledge nothing has been published concerning their potential danger to other bivalves.

During 1953 laboratory and field observations were made of suspected enemies of the hard clam. The mud crab, *Neopanope texana*, was considered because of its abundance in hard clam areas under study in Narragansett Bay.

LABORATORY OBSERVATIONS

In one experiment carried out during June and early July, 50 hard clams (average length 10 mm) were allowed to dig themselves into the sand bottom in a tank supplied with running water. Five mud crabs (average width 15 mm) were then introduced into the tank. At the end of 30 days, the experiment was terminated and the crabs removed from the soil by screening. Thirty-three of the 50 clams had been broken to the extent that only by counting hinge pieces could the amount of predation be directly determined.

In another experiment during September, 37 set-of-the-year hard clams (1-7 mm in length) were allowed to bury themselves in the sand bottom of a running water tank. Twenty-five clams (15-25 mm in length) were allowed to become established in the sand of a second tank. Three mud crabs (approximately 15-20 mm in width) were added to each tank. In 18 days when the experiment ended, all 37 of the set-of-the-year hard clams had been crushed and eaten. Four of the clams in the second tank had been opened. These had not been crushed; instead, the lips of the valves were chipped as though the crabs only gradually gained access to the soft parts. The victims measured 13, 16, 17, and 17 mm in length.

A third experiment carried out in November gave some information on the predaceous activity of *Neopanope* in relation to lowered water temperature. This experiment was begun in tanks of aerated water at summer temperatures of 20-23°C. Eleven hard clams (1-9 mm in length), and two mud crabs (15 mm in width) were placed in one tank with no sand bottom for the clams to dig into. In the second tank, also without soil, were placed 11 hard clams (14-33 mm in length) and two mud crabs. Within 24 hours, all but one of the clams in the first tank had been crushed and eaten. None of the clams in the second tank had been opened nor was there any evidence of attempt. Aeration was discontinued and the running water supply turned on. In a short time, the water temperature was down to 12.5°C. Thirty hard clams (1-9 mm in length) were added to the first tank. The original crabs were retained. At the end of the next 24 hours, 11 clams had been crushed. At the end of another 24 hours, eight more clams had been destroyed. During the next three days, the remaining 11 clams were crushed and eaten. During this time the water temperature fluctuated between 11°-12.5°C. No evidence of predation in the second tank was apparent at any time during this experiment.

FIELD OBSERVATIONS

During the fall of 1952, 2,000 set-of-the-year hard clams (2-6 mm in length) were planted in a 6′ x 3′ bottomless box sunk into the intertidal flats in Wickford Harbor, Rhode Island. The object was to measure the growth rate of the clams and the extent of predation by the oyster drills *Urosalpinx cinera* and *Eupleura caudata* which are common in the vicinity. Coarse mesh hardware cloth was used as a cover to exclude the blue crab *Callinectes sapidus* and curious diggers. In November 1953, the clams were redug. Only 258 individuals were recovered (8-20 mm, average 13 mm in length). In addition, 39 broken and chipped paired shells approximately the same size as the live clams were screened out. Only 13 shells of any size were found with drill holes. Present in the box were 11 *Urosalpinx* and 48 *Neopanope*. The fate of the missing clams can only be a subject for speculation. However, in the light of observations in the laboratory, it is conceivable that mud crabs were a major contributing factor in decimating the planting while the individuals were still very small.

The data presented show that the mud crab is a menace to small hard clams and is particularly voracious in its predations on clams less than 10 mm. in length. *Neopanope texana* is described as common to very common along the whole Atlantic Coast from Prince Edward Island to Florida (Pratt 1948 and Miner 1950). This is practically coincident with the range of the hard clam. If the above observations are typical of *Neopanope* activity, it must be considered a potential enemy to the hard clam throughout its range.

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WARREN S. LANDERS
U. S. FISH AND WILDLIFE SERVICE,
KINGSTON, RHODE ISLAND

lvantages of Producing Seed Oysters Inshore

Dr. V. L. Loosanoff says shallow areas yield good sets more regularly and furnish protection against storms and enemies*

Left: With oyster tonging skiffs still in tow, one of the York River (Va.) Oyster Corporation's larger boats is tied to the wharf as the catch is loaded on a truck. Right: Unloading of oysters from the firm's "Sea Rac No. I". The York River Oyster Corporation produces in the neighborhood of 75,000 bushels of oysters annually from the York River. Where the ground is firm, the Corporation plants seed oysters which are ready for harvesting in two to three years' time. Loads of shells are dumped in other areas to create a hard bottom, to which the oyster spat can attach themselves.

ɔORDS show that between 1904 and 1925, a period f 21 years, not a single general, heavy set of oysters ccurred in Long Island Sound. During this time dustry survived by buying abundant seed oysters ew on so-called natural beds which were located in shallow inshore waters. Since 1925, there have ood sets only in five years—1930, 1939, 1940, 1944 45.

ther words, Long Island Sound oystermen have in st 54 years, had only six or perhaps seven good, l sets. The remaining years were either complete s or so-called marginal years, during which a general ight set occurred in the Sound, or when good sets ed only in certain sections. This year the oyster ry suffered another setting failure, and as a result men are in need of young oysters.

farmer gathered a commercially-profitable crop very eighth or ninth year, how long could he continue to exist, and should he not look for other tracts of where more regular and more abundant crops could own? I think he should, and the Connecticut oyster ry, imitating a wise farmer, also should consider the ility of transferring a substantial portion of its seed production operations from the open waters of Island Sound to more promising areas. I do not ate a complete change, i.e., abandonment of the beds in Long Island Sound proper. I merely suggest he extension of our oyster cultivating efforts into w, more protected waters where the conditions for ction of seed are more promising.

Uncontrollable Conditions

st of the conditions affecting the oyster industry in Island Sound proper are virtually uncontrollable. conditions may be either of physical or biological e. The most outstanding examples of the former are ighly destructive storms. The industry still remembers that of November, 1950, which killed millions of rs and ruined many beds. Nothing could have been to prevent this catastrophe because the storm came out warning.

the biological factors we would probably think, first of all, of such well known enemies as starfish and drills. It is true that they may be eliminated from small areas by the persistent use of lime, mops or suction dredges, but they will continue to invade the beds from the surrounding grounds which remain uncleaned. Furthermore, as is well known, starfish have pelagic larvae, which are carried around by the currents and which may set in immense numbers on an oyster bed no matter how bare of adult starfish the bed may be.

We know of several formerly extremely productive oyster setting areas which eventually were given up because it became economically unprofitable to defend these beds against the enemies.

Thus, it is clear that the open Sound is not only an unreliable place for getting sets regularly but also a place where if the set does occur, it remains difficult and expensive to protect it against enemies. The question that naturally arises because of these considerations is what the industry could or should do to place itself in a more advantageous situation. The answer may be that a partial solution of this problem could consist in the utilization of numerous bays, harbors and deltas of rivers where extensive natural beds of oysters existed in the past, but which at present are barren and useless.

Our observations, as well as those of our predecessors in biological phenomena, show clearly that oyster set rarely fails in inshore waters. We estimate, for example, that in Milford Harbor and Indian River, if these waters were properly planted and managed, a set of commercial importance could be gotten nine out of every ten years. Furthermore, beds located in bays and harbors would be better protected against storms.

Finally, because the salinity of the water in many inshore areas is comparatively low, the oysters, especially young set, would be protected by nature itself against starfish and drills, which require a comparatively high salinity to exist and propagate. This consideration alone is of tremendous practical significance because it eliminates from the debit side of the companies' ledgers astonishingly high sums of money spent on pest control.

Effect of Pollution

A criticism of our suggestion may be offered by pointing out that most of the inshore waters are more heavily

(Continued on page 41)

Loosanoff is director of the Fish & Wildlife Service Laboratory at Milonn. The accompanying article is based on a paper he presented at the Oyster Convention in Boston, Mass.

Atlantic States Commission Meets in Baltimor

Favors banning uncertified foreign shellfish, and discusses possible research projects under Saltonstall-Kennedy Act

Wayne D. Heydecker, secretary-treasurer of the Atlantic States Marine Fisheries Commission.

THE Atlantic States Marine Fisheries Commission, at its 13th annual meeting held October 4-6 in Baltimore, Maryland, unanimously adopted a resolution expressing officially its conviction that foreign shellfish which does not meet the sanitary standards required of domestic oyster and clam producers should be kept out of the country.

The resolution does not affect Canada because that nation already has a working agreement with the United States on shellfish sanitation and requires its producers to meet the same high standards required of shellfish producers in the U. S. Adoption of the resolution came after commissioners from shellfish-producing States had expressed the fear that importation of uncertified shellfish might result in harm to the consuming public which in turn might not differentiate between certified and uncertified shellfish products.

The Commission unanimously elected Charles M. Lankford, Jr., Virginia Fisheries Commissioner, as chairman for the coming year. Chosen as vice-chairman was John Miller, shrimp producer of St. Mary's, Georgia. The secretary-treasurer of the group is Wayne D. Heydecker.

Section chairmen were elected as follows: North Atlantic Section, John B. Bindloss of Stonington, Conn., retiring chairman of the Commission; Middle Atlantic Section, Assemblyman E. T. Barrett of Bayshore, N. Y.; Chesapeake Bay Section, Arthur H. Brice, chairman of the Maryland Department of Tidewater Fisheries; South Atlantic Section, G. Robert Lunz, director of Bears Bluff Laboratories, Wadmalaw Island, S. C.

Asks Rebuilding of Laboratory

The Commission renewed its request for the rebuilding of the 70-year-old laboratory of the Fish & Wildlife Service at Woods Hole, Mass., badly damaged by four hurricanes two of which last month carried away the docks. This modernization, said the Commission, is urgently needed for important research in the States of the North Atlantic and Middle Atlantic Sections and for the International Commission on the Northwest Atlantic Fisheries.

At the request of the same two Sections the Commission urged the Fish & Wildlife Service to initiate biologic studies of scallops, whiting and menhaden and to investigate the causes of recent oyster mortality. It also asked for studies on the economics of the sea scallop industry, effects of dragging on the bottom, extension of the present technological program in New England waters dealing with exploratory fishing and freezing whole fish at sea.

A Middle Atlantic Section request that funds from the Saltonstall-Kennedy Act be made available under an equitable system of apportionment to competent State research agencies, was endorsed by the Commission. The Middle Atlantic Section accepted in principle a proposal that State fishery agencies in New York, New Jersey and Pennsylvania be authorized to cooperate with each other and to adopt flexible regulations covering all species of fish that go up the Delaware River to spawn.

A resolution recommended by the Chesapeak
Section opposing a reported plan to dump anthraci
mine waste or any other industrial wastes into the
peake Bay or any of its tributaries, was adopted
endorsed at the petition of the South Atlantic
was a request to the Fish and Wildlife Service to
the shad program which in its first six years ha
tributed much valuable data, and to enlarge and ca
the economic and marketing study of shrimp just

Urges Study of Vessel Design

Francis W. Sargent, director of the Massachusett
sion of Marine Fisheries, spoke in favor of a gene
search project on vessel and equipment design.
expressed a belief that the accident rate aboard
vessels is one of the basic problems of the indust
suggested an intensive study by engineers would
inate or minimize the dangers from exposed
winches and other deck gear.

Mr. Sargent also said he hoped that the whiting
which is being conducted by the Woods Hole, Mas
ing boat *Priscilla V.*, under charter to the Fish & W
Service, can be completed in a few months. The
chusetts Marine Fisheries Director added that he
ticularly gratified that Maine's representatives
agreed to the research into mesh size for whitin
with a promise they will work for companion fishe
once the best net size is determined. The whiting re
program also calls for a long-range biological st
the fish to determine how their numbers can be inc

Scallop Research Requested

Need for a four-point program supported by Salto
Kennedy Act funds to aid the New Bedford,
scallop industry, was pointed out by John F. Li
general manager of the Seafood Producers Asso
Inc. He requested activation of a program in mar
velopment, research, annual production quotas a
port quotas, in order to insure a prosperous
industry.

Mr. Linehan commented: "We do not have the res
to develop national or regional market areas. De
ment of the sea scallop market must be included

Research on the mesh size of whiting nets is being done by
Woods Hole, Mass. dragger "Priscilla V.", which is under ch
the Fish & Wildlife Service. She is owned by Capt. Jared V

~~. for practically the entire production in Mon-~~
~~unty.~~

~~the seven-month period ending with July,~~
~~8 million lbs. of fishery products were landed at~~
~~ey ports. Menhaden accounted for 90 percent~~
~~ndings for this period. Scup or porgy was in~~
~~lace followed by surf clam meats which are~~
~~this area. Receipts of sea bass were nearly a~~
~~bs. below the landings of this species for the~~
~~ding period of the previous year.~~

~~yster Beds Closed~~

~~yster beds in Great Bay, Mullica River and~~
~~reek were closed by resolution of the Shell~~
~~Council from sunrise on October 1 to sunset on~~
~~r 30.~~

~~l of 8200 bushels of seed oysters have been~~
~~in the Mullica River in recent months. Turtle~~
~~ed was planted with 5200 bushels of seed, while~~
~~hels were planted on Oyster Point Bed.~~

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cing Seed Oysters Inshore

ed from page 13)

, industrially and domestically, than Long Island
roper. This should be admitted, but since the
icut industry is chiefly concerned with seed oysters
ill not be sold for several years, the matter of
n does not enter into the picture. Furthermore,
ervations indicate that, as far as tolerance to
and industrial pollution is concerned, oyster
nd young set may be hardy organisms.

this conclusion on observations that good sets
ve occurred in the Quinnipiac River in New Haven,
ock River, Bridgeport, and Housatonic River,
rain the most heavily industrial areas in our State.
may recall that during 1944 when all our indus-
ere at their maximum production for the war
nd when due to the inflow of hundreds of thou-
industrial workers the problem of domestic pollu-
ame quite acute, we had one of the best oyster
e 1900.

of course, does not indicate that pollution is de-
or harmless to oyster larvae. It merely shows that
possess quite a tolerance and, therefore, rivers
re slightly polluted should be considered among
s capable of producing heavy sets. Furthermore,
end toward pollution abatement continues, pollu-
y not be a problem at all.

Inshore Waters Now Public Grounds

hief obstacles to the utilization of natural oyster
ng bottoms are, in my opinion, the archaic regula-
hich designated most of the inshore waters as
grounds. In other words, these areas cannot be
to private individuals or companies for cultivation
fish. The regulations, which in the past perhaps
esirable, have led to the situation where we find
jority of our potentially most productive Connect-
a oyster beds virtually barren due to lack of care.
from economical and biological points of view,
rounds are now entirely wasted. Since there is
ally no one making a living from inshore beds in
ea, logically no one would suffer if some of the
s were leased for cultivation to private individuals
panies. By proper cultivation of the inshore beds
ustry would become assured of an abundant annual
of oysters, and the township in the State would
ditional revenue.

zation of numerous shallow salt water ponds also
constitute part of the program. Some of the ponds
tha's Vineyard have proven quite productive, and
dies which we initiated with the help of some Con-
t oyster companies along the same line suggest that
onds eventually may be utilized not only for the
tion of seed oysters but also for clams.

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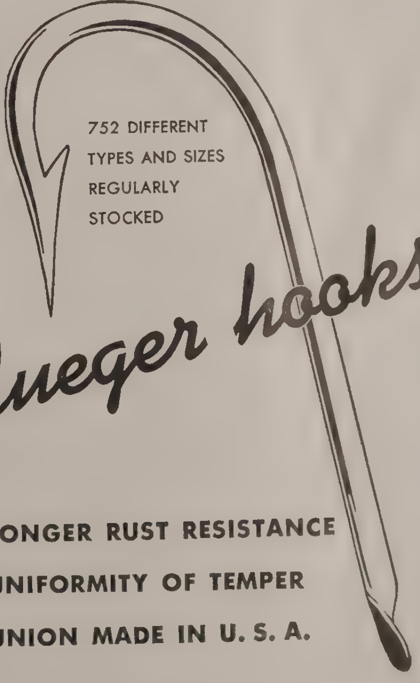

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Canadian Report

By C. A. Dixon

Sardine seiners of southern New Brunswick, whe have been extremely scarce this Fall, are now engag rounding up sardines at the most southwestern p Nova Scotia. Large catches have been made in the Sable Island region by seiners from Charlotte C Many sardine carriers from New Brunswick and e Maine ports have converged in the Clark's Harbor and hundreds of hogsheads of the fish are being ta the factories at Black's Harbor, Eastport and Lubec.

The strike in Nova Scotia waters, although far fro manufacturing plants, has proved itself a boon to al cerned. For the most part the fish are good sardin though there are some large herring among them. Lubec and Eastport factories are very busy at the ti writing as are the packing plants of Connors Bros. in New Brunswick.

Fishermen Catching Hake

Southern New Brunswick trawlers and dragger landing average-size fares of groundfish, with hak most plentiful. Scallop fishermen are getting from 25 gallons to a boat, and the higher price received fo bivalves this year makes it possible to operate the at a profit. So far only a limited number of boat engaged in the work.

Ashore, hundreds of fishermen are busy rigging up lobster gear in preparation for the opening of the season this month. A number of fishermen at G Manan had to build many new traps to take the pla those destroyed by hurricanes when heavy seas s the stored traps from the tops of breakwaters wharves. It is expected, however, that more traps w fished this year than last owing to poor prospects in lines of fishing.

Landings Show Gain

Canada's sea-fishermen landed 10.3 per cent more this August, and the catch was worth 20.7 per cent than in the corresponding month last year, accordi the Dominion Bureau of Statistics.

In the January-August period landings of fish ro 1,251,657,000 lbs. from 1.101.000.000. and the value cli to $56,419,000 from $55,479,000.

Scarcity of Clams

Fishermen in Charlotte County, N. B. are finding c very scarce this Fall, and are reporting production at a half barrel to a man in a day's digging. The ov production has showed a marked decline this year.

Dulse Pickers Have Poor Season

Dulse pickers at Grand Manan, N. B. have experie a very poor season because of the continuous rainy wea which prevented the drying of the dulse as in no seasons. Then the hurricanes caused such a run of h seas in the Bay of Fundy that the dulse was swept of the rocks upon which it was rooted.

Fishermen Show Ingenuity

Capt. George Lovelace and his son Murray and Bu Hamilton of the fishing vessel *Alvin and Paul* of Lo port, N. S., got out of a bad situation when their batt ran down recently. There was no crank aboard which to start the dual engines, so they fashioned on of the anchor stock, using their cabin stove for a f They were two days sawing, heating and hammerin iron stock. At the end of the second day they tried crank and one of the engines started, permitting the reach port.

Reprinted from AMERICAN SCIENTIST, Vol. 42, No. 4, October 1954

NEW ADVANCES IN THE STUDY OF BIVALVE LARVAE

By V. L. LOOSANOFF

U.S. Fish and Wildlife Service Laboratory
Milford, Connecticut

THIS article is concerned with recent developments and improvements in the methods for obtaining eggs and sperm of bivalve mollusks and for growing the larvae in laboratory cultures. It also discusses briefly certain results that have been achieved because of the successful use of these methods, many of which were developed at our laboratory during the past few years.

Several reasons led us to enter the field of culturing bivalve larvae. First, the development of a method by which larvae could be grown successfully under controlled conditions would open a wide field for studies of the physiological and ecological requirements of these important animals (Fig. 1). In other words, the opportunity would then be offered to ascertain the effects of different factors of environment, such as temperature, salinity, pH, turbidity, quantity and quality of food, etc., upon the rates of growth and survival. All these factors, of course, could be studied either singly or in various combinations which eventually would reproduce the complexity of conditions existing in nature.

The second consideration was the hope of investigating the field of heredity and selective breeding of bivalves. Although some skepticism may be expressed concerning the practicability and, especially, the possibility at this time of establishing strains of mollusks with new and desirable characteristics—such as unusually rapid growth, high content of glycogen in the tissues, and resistance to diseases, or of evaluating the prospects of interspecific hybridization—preliminary studies in this field have already been undertaken and have produced valuable data. For example, Davis' experiments [1] have shown that cross-fertilization between the American oyster, *Crassostrea virginica*, and the Japanese oyster, *Crassostrea gigas*, is possible, but the hybrid larvae die within a few days. Thus, one of the most important questions asked in connection with the introduction of Japanese oysters in the waters of Eastern United States was satisfactorily answered.

More recently it has been demonstrated that two closely related species of the hard-shell clam, or quahog (*Venus mercenaria*) of Long Island Sound and *Venus campechiensis* of the Gulf of Mexico, could be crossed. The hybrid larvae grow to metamorphosis at a rapid rate, showing what may be a case of typical hybrid vigor. Finally, it has been shown that the vitality of larvae of oysters and clams and their rate of growth are unrelated to the size or age of the parents [2]. Obviously, the importance of these contributions to the field of molluscan biology cannot be denied, and it may now be safely assumed that the genetics of bivalves has been taken out of the area of merely theoretical discussions and made a reality.

The third field, which depends upon our ability to grow larvae in the laboratory throughout their entire period of development, is that of identifying various species of larvae in plankton collections. Because the early, and sometimes even the advanced, stages of larvae of many species of bivalves are much alike in size and appearance, it is often impossible to place them, with any degree of certainty, in a definite group. But this difficulty can be overcome if the investigator has in his possession preserved samples of larvae of known origin, or at least their photomicrographs and measurements. However, because until recently such helpful standards were not available we are inclined to believe that several investigators, in their attempts to place bivalve larvae collected in plankton in a definite genus and especially species, were often in

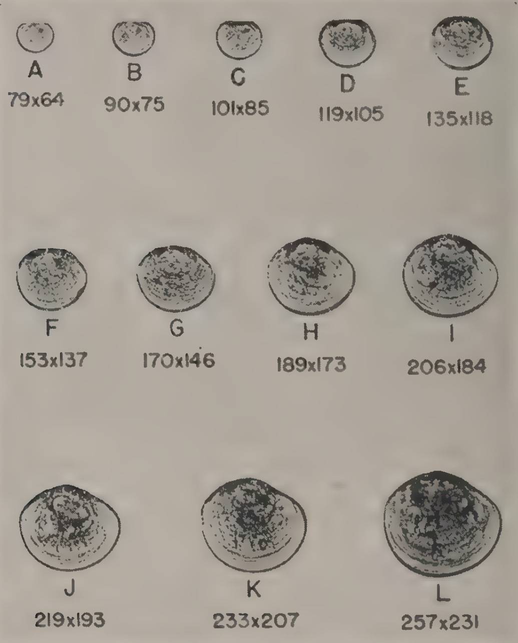

Fig. 1. Different stages of development of larvae of the surf clam, *Mactra* (*Spisula*) *solidissima*, from early straight hinge shelled stage (*A*) to the stage at which metamorphosis into a juvenile clam occurs (*L*). Measurements in microns.

error. For example, Stafford maintained that the larvae of our common hard-shell clam grow to approximately 450μ before their metamorphosis occurs. However, in all our work with the larvae of this species, which have been grown successfully during the past seven years under extremely varied ecological conditions, we have never found a larva measuring much more than half the size indicated by Stafford. Obviously, he was not working with larvae of *V. mercenaria* but of some other species, yet lacking standards for size and shape, he had no means for positive identification.

The accuracy of the identifications made by more recent investigators also seems doubtful, because we find significant discrepancies when comparing the shape and size of larvae, which were grown at our laboratory from known parents, with the descriptions, measurements, and photographs of larvae of presumably the same species as offered by those investigators [3].

Another field, which until recently was virtually closed to investigators, includes larval diseases, parasites, and their control. Fortunately, the ability to raise larvae in the laboratory as a matter of routine has opened this field also, and, as will be shown later, some important initial steps have already been made.

Finally, it may eventually become feasible to produce a commercial supply of young mollusks by depending chiefly upon artificial methods of propagation. To be successful in this, however, it will be necessary to make substantial progress in the fields already mentioned.

I wish to emphasize that workers at the Milford Laboratory are not the first who have tried to grow bivalve larvae. Since the time of Brooks, this has been attempted by several investigators. The accomplishments of many of these people are discussed in two excellent reviews offered by Korringa (1941) [4] and Thorson (1946) [5]. Readers seeking additional information in this field may find it in these two papers. However, most of their work was done on eggs or newly hatched larvae, and, with the exception of a few investigators, the larvae were rarely grown beyond the so-called straight hinge stage. Some workers, after many failures to raise the larvae to the stage of metamorphosis, finally concluded that, because of the small size and delicate nature of the eggs, there could not be a practical method of raising the larvae to the setting stage.

In recent years the situation has remained such that there was no simple and reliable method for growing larvae [7, 8]. Even as recently as 1953, Yoshida, in his attempts to identify the larvae of the commercially important bivalve mollusks of Japan, had to depend on removing the larvae from plankton and cultivating them until they metamorphosed and grew into small clams—a slow and not entirely dependable approach because juvenile individuals of many species are almost identical in shape and size and, therefore, easily mistaken for each other.

Methods of Experimentation

As is well known, the spawning season of bivalves in the New England waters is confined almost entirely to the summer months and is therefore of short duration, lasting about 2½ to 3½ months. Necessarily, experimentation with eggs and larvae was confined to the same period. Fortunately, we discovered in 1944 that by keeping oysters in warm water, the development of the gonads could be induced and healthy spawn obtained even in winter. As a result it was decided to provide the laboratory with warm running sea water during the cold period [9]. The advantages of having warm sea water throughout the year are numerous; particularly the possibility of conducting experiments continuously instead of being confined to the short summer period.

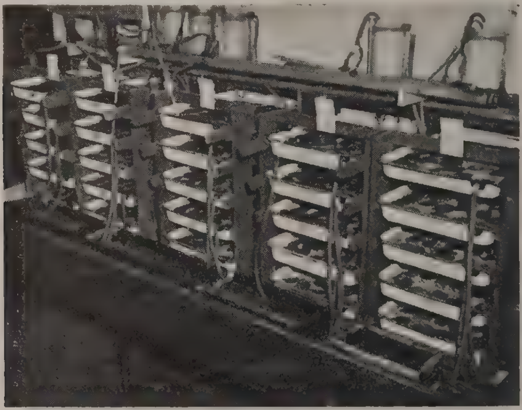

FIG. 2. Racks of trays with warm running sea water in which bivalves are conditioned for spawning. By placing the trays over each other in special racks much space can be saved.

The method for conditioning bivalves for spawning in winter and spring is relatively simple. The adult mollusks are brought to the laboratory from the natural beds, where the temperature of the water in winter may be as low as 0°C and placed in trays with a flow of sea water maintained at a temperature of about 7–8°C—just high enough to allow the animals to become slightly active (Fig. 2). Later the temperature is gradually increased several degrees per day until it eventually reaches about 20–22°C. This conditioning period usually takes from two to three weeks, but can be shortened by placing the animals directly into water at a temperature of 20°C. So far we have no evidence that the gametes obtained from parents which were subjected to such a sharp physiological shock are less viable than those from slowly conditioned parents. However, we usually avoid sharp temperature changes.

The conditioning period can also be shortened by keeping the mollusks at a temperature higher than 20°C. For example, by keeping adult Long Island Sound oysters at a temperature of 30°C in winter, ripe sperm and some fertilizable eggs can be obtained after three days of conditioning. Spawning can be induced in approximately 38 per cent of the oysters after only five days [10]. However, we found that the temperature required by the northern oysters for breeding is considerably lower than for southern oysters. Therefore, even when kept under the same conditions the northern oysters show a more rapid rate of gonad development and can be induced to spawn earlier than those from southern regions.

Conditioning bivalves for reproduction during the fall and early winter is not possible until they have recovered from the natural summer spawning. The recovery normally includes the resorption of old gonad tissues and the accumulation of new reserve materials, such as glycogen. In our New England waters the end of the post-spawning recovery may not be reached by some bivalves until early November, and therefore sex products are not available during the intervening period.

To solve the problem of a supply of eggs and sperm during these months we devised a method to delay the spawning of ripe or nearly ripe mollusks until late autumn or even later. The mollusks were taken from the waters of Long Island Sound early in the summer before spawning and replanted in colder waters, such as those of Boothbay Harbor, Maine. Here the water temperature permits a slow development of the gonads but, nevertheless, is low enough to prevent the transplanted mollusks from spawning. Thus, by the time the oysters and clams in Long Island Sound have spawned and are completely spent, those kept in the Maine waters still retain their spawn and may be induced to spawn in the laboratory to provide normal gametes during the late summer and fall.

Similar results were achieved by keeping ripe mollusks in insulated laboratory tanks through which mechanically-cooled water flows, but such a method, of course, becomes too expensive if large groups of animals have to be kept under such conditions for several months.

Using a combination of the two methods as just described, it is now possible to experiment with the gonads, gametes, and larvae of bivalves throughout the entire year, and as much can now be accomplished in one year as could formerly be done in three or four years. This is, obviously, an important biological achievement, but for those who are interested in the physiology of oysters, another important question remained, namely: Are the development of gonads and the spawning of oysters and other bivalves initiated and regulated by periodical changes of nature (exogenous) or are they directed by a pattern within the organism itself (endogenous)? The answer has been given by our experiments which demonstrate that oysters are able to develop normal gonads and to spawn at approximately six-month intervals. This occurred on five consecutive occasions. In other words, we now know that there is nothing in the biological pattern of oysters that will prevent the production of gametes oftener than once a year, provided the surrounding conditions are suited to the physiological activities associated with this process [11].

Furthermore, the experiments show that gonad development is independent of seasonal changes, such as day length, tidal rhythm, precipitation, and other phenomena that normally occur in New England waters in late spring and early summer when the gonads are ripening. The experiments also showed that gonad development does not depend on the presence of definite types of plankton which are in the water only during the late spring and early summer, the time of normal gametogenesis. The results with oysters were corroborated by similar experiments with clams, *V. mercenaria*, which also spawned normally in the January-June-January pattern.

Because the mollusks used for spawning in this laboratory are often kept under somewhat crowded conditions in the trays, they may not receive enough natural food. To ameliorate these conditions a large supply of plankton was needed that could be added to the running water supplied to the experimental animals. Considerable quantities of plankton were also needed to feed the numerous cultures of larvae grown in our laboratory. Fortunately, by utilizing the method of growing plankton by adding commercial fertilizers to sea water—a method which we developed several years ago—sufficient quantities were grown, without undue difficulty, in large tanks.

While it was relatively easy to maintain in this way an adequate supply of plankton during the summer, the situation changed radically during the cold season when it was impossible to maintain the plankton cultures in outdoor tanks. The problem was solved by building a special enclosure, essentially a greenhouse, with a shallow 3000-gallon wooden tank enclosed for growing plankton, and heated to maintain the temperature at the desired level. To provide the additional light needed during short dark days special light fixtures were installed. As a result of these improvements, large quantities of plankton can be grown at any time during the year, even in the coldest weather.

The method of inducing spawning in ripe mollusks is as follows: The mature animals are taken from the conditioning trays and placed in smal glass dishes. These dishes, in turn, are set in a large tray in which warm or hot water is poured (Fig. 3). The increase of temperature in this tray rapidly brings the temperature of the sea water in the small dishes, in which the bivalves are kept, to the desired level. This is the method o thermal stimulation, the principle of which was known many years ago [6], and which has been widely used during the last three decades.

In addition to stimulation by a rapid increase in temperature, the ivalves are stimulated to spawn by adding to the water small quantities f sperm or of egg water of the same species. This method is based upon a ıggestion originally made by Professor Trevor Kincaid of the University f Washington to McMillin [12] of the former Bureau of Fisheries.[1]

Mature normal bivalves of most species, which have so far been tried, sually respond to a combination of thermal and chemical stimuli. However, not all species respond equally well to this combination treatment. ome species require only a small increase in water temperature to bein spawning, whereas others may require prolonged use of both stimuli or several hours before responding. Still others, such as the common nussel, *Mytilus*, will not respond to these stimuli. Iwata has found that a ipe mussel can be induced to spawn by stimulating its adductor muscle with an electric current. Finally, in some species of bivalves, for example *Pitar morrhuana*, we have been unable to induce spawning by any known method.

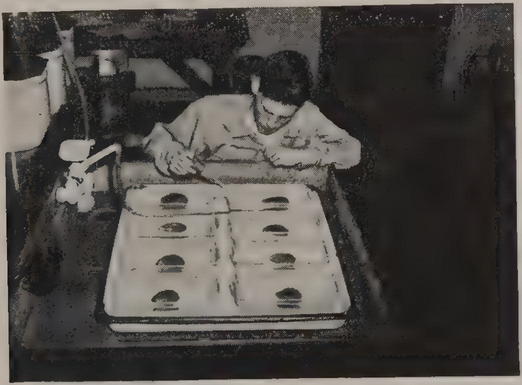

FIG. 3. Method of spawning ripe bivalves. The oysters, each in a separate glass lish, are stimulated to spawn by a rapid rise of the water temperature.

The fertilized eggs, accumulated in the dishes at the end of the induced spawning, freed from the debris by using a series of fine screens, are next placed in the sea water of the hatching vessels, usually 5-gallon earthenware jars. It has been found desirable to leave the developing eggs un-disturbed until they reach the swimming larva stage when they are protected by newly formed shells. This usually takes between 24 and 48 hours, depending upon the temperature of the water in the hatching vessels. After that, the water in the jars is changed every 24 to 48 hours. In these changes the water is again strained through fine sieves which retain the larvae. They are then returned to the jars which are filled with new water that has been passed through cotton filters to remove silt and possible larval enemies. Using these techniques, the larvae of several species of bivalves have been successfully cultured through metamorphosis.[2]

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[1] McMillin reports this event as follows: "The theory of mass spawning as touched upon in the former report might be referred to here. This theory was given by its originator, Trevor Kincaid, before a meeting of the American Association for the Advancement of Science. It has never been published in pamphlet form and no experimental evidence in proof of it is known to exist.

In substance the theory is that marine animals, oysters as here referred to, in densely populated areas will spawn unanimously in response to a stimulus, the nature of which is unknown but probably given off by the animals themselves, and when in proper density excites spawning in all affected animals." Kincaid's idea has been further developed by other investigators and now the method based on it is commonly used to induce spawning of bivalves.

It has been our experience that some of the discharged eggs of the various species of bivalves do not possess normal vitality. Probably some of the females are compelled, by strong temperature stimulation, to discharge their eggs before they are fully ripe; such eggs produce feeble larvae which soon die. The last batches of eggs spawned by virtually spent females may also produce feeble larvae. Finally, normal eggs may be injured through improper handling, such as high temperature, or by other means. Fortunately, abnormal larvae that develop from injured or defective eggs are easily distinguishable from normal ones and may be discarded.

In using spawn for experimental purposes it was necessary to determine at what age bivalves produce the highest percentage of viable gametes. The same question was also frequently asked by people interested in commercial shellfisheries, and by those managing oyster or clam resources in different States. The results of our experiments with oysters and clams in which individuals of the oldest group were estimated to be between 30 and 40 years old and the youngest less than two years old, indicated that there was no significant difference in the time required for bivalves of different age-groups to develop ripe gonads, and that the eggs from all age-groups usually gave almost 100 per cent fertilization. Also the percentage of early shelled larvae secured showed no consistent variations that can be ascribed to the size or age of the parents. Finally no significant difference was found in the rates of survival of the larvae that originated from parents of different ages. On the basis of these results we have concluded that any age or size group could be used as a source of spawn [2].

Food Requirements

It became evident in the early stages of the investigation that larvae of different species of bivalves have characteristic food requirements. In general, all the species grown so far can be separated into two groups—one group that is able to utilize only a few of the many microorganisms available for food, and another group which thrives on almost any organism small enough to be ingested. The first group is well represented by oysters, both Atlantic and Japanese.[3] The other group is best represented by larvae of the hard-shell clam, or of the common mussel.

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[2] Among them I may mention the American oyster, *Crassostrea virginica*, the Japanese oyster, *Crassostrea gigas*, the Pacific Coast oyster, *Ostrea lurida*, the European oyster, *Ostrea edulis*, the hard-shell clam, *Venus mercenaria*, and its southern relative, *Venus campechiensis*, hybrids of these two species of Venus, the soft-shell clam, *Mya arenaria*, the surf clam, *Mactra (Spisula) solidissima*, the common mussel, *Mytilus edulis*, the small boring clam, *Petricola pholadiformis*, *Pitar (Callocardia) morrhuana*, the razor clam, *Ensis directus*, the jingle-shell, *Anomia simplex*, and the little surf clam, *Mulinia lateralis*.

A good illustration of the differences in the food requirements of these two groups of larvae was supplied by the following experiment. Larvae of the oyster and the clam of the same age were placed in approximately the same numbers in the same experimental jar. Mixed plankton consisting mostly of cells of the green algae (*Chlorella*), but also containing many other microorganisms, was then added as food. Samples of the larvae were taken at frequent intervals and measured, and their rate of growth estimated, as well as the mortality rate. The data showed that the clam larvae grew rapidly, while the oyster larvae remained the same size and also showed a heavy mortality. Finally, the clam larvae metamorphosed in about 13 days, whereas most of the oyster larvae died without showing any appreciable increase in size.

The experiment was repeated, but instead of having larvae of two species in about equal numbers, the ratio was changed to approximately one clam larva to ten oyster larvae. This was to make sure that the clam larvae, normally somewhat larger in the early stages of development, did not deprive the oyster larvae of food. The results obtained were the same as in the previous experiment. The clam larvae grew well and finally metamorphosed, but the oyster larvae remained the same size as at the beginning of the experiment, apparently because of their inability to utilize the food cells that were so abundantly present in the surrounding water.

The experiment was repeated once more but this time the larvae were cultured in large outdoor tanks, each with a capacity of several thousand gallons. Larvae of our hard-shell clam and of the European and American oyster[4] were used. The first two grew to metamorphosis, the latter showed virtually no growth and finally died—a corroboration of the previous results.

As is evident from the preceding experiment, it became necessary, as our work progressed, to employ analytical methods to study the quantitative and qualitative food requirements of larvae, which, as just noted, may vary with the species of larvae, or their age, or with the species of the organisms supplied for food. We found that, contrary to the generally accepted view, organic detritus is not utilized by clam larvae or by oyster larvae (3, 13). Furthermore, clam larvae generally thrived on sulfur bacteria, but oyster larvae could utilize neither this form nor any of the other 13 species of marine bacteria supplied as food. This last fact is rather interesting because it contradicts another generally accepted belief that marine bacteria constitute an important part of the diet of oysters.

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[3] *Crassostrea virginica* and *C. gigas*.

[4] *Venus mercenaria, Ostrea edulis* (European oyster), and *Crassostrea virginica*.

Davis has made the interesting observation that while young oyster larvae cannot utilize the cells of a green alga such as Chlorella, older larvae of the same species are able to do so. It had already been suspected that larvae of several species, such as the hard- and soft-shelled clams and even the European oyster, can be grown on a Chlorella diet. The experiments of Davis in which a pure culture of these cells was used confirmed the belief that bivalve larvae are able to utilize certain of the green algae as food [13].

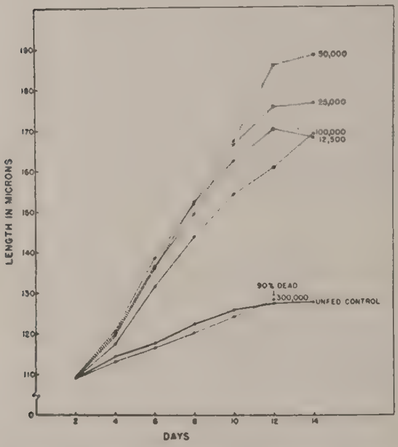

FIG. 4. Mean length of larvae of round clam, *Venus mercenaria*, of different ages in cultures kept at the same population density of 6.5 larvae per cc but given different numbers of cells of large Chlorella per cc of water.

In another series of experiments clam larvae were grown to metamorphosis in about 12 days while being fed solely on a pure culture of Chlorella.[5] Clam larvae also grew well in cultures of any one of the following three flagellates: *Chlamydomonas*, *Chromulina*, and *Isochrysis;* cultures were received from the Plymouth Laboratory, England. The experiments established two important facts, namely, that clam larvae can survive on a very restricted diet, actually consisting of a single food species; and that the larvae can utilize green algae during all stages of development. These conclusions differ from those of some European workers who maintain that bivalve larvae cannot grow or survive on such a diet because they do not possess a certain enzyme necessary for the digestion of cellulose which composes the cell-walls of algae.

In some of our earlier experiments, clam larvae were supplied with approximately 300,000 small Chlorella cells about 3 μ in diameter, per cc of water in which they were kept. The larvae so fed grew well, but we still lacked knowledge as to the optimum concentrations of food organisms for growth and survival of these larvae. The problem had to be ap-

[5] Chlorella was isolated for us from the sea water of Milford Harbor by Dr. Ralph Lewin formerly of Yale University.

proached by evaluating, first, the effects of different concentrations of the same food organism. Therefore, the clam larvae, kept at the same population density of 6250 individuals per liter of culture medium, were given different quantities of food. The principal foods tried were Lewin's pure culture of Chlorella with cells averaging 8 μ in diameter, or a mixed culture of plankton which consisted largely of a smaller form of Chlorella with a cell size averaging about 3 μ.

The rates of growth and survival of the larvae showed that the optimum concentrations of food depended upon the size of the food cells. When large Chlorella cells were used the optimum concentration was approximately 50,000 cells per cc (Fig. 4), whereas approximately 400,000 to 500,000 smaller cells per cc were needed to maintain the growth of larvae at the same rate [14].

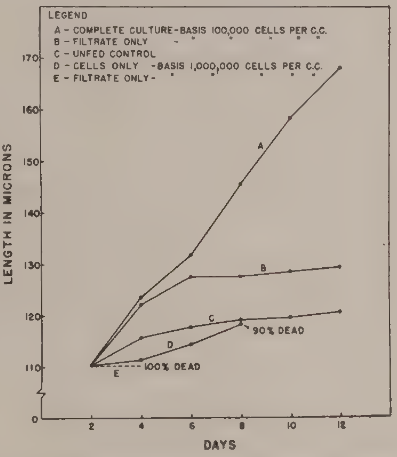

FIG. 5. Deleterious effects of heavy concentrations of Chlorella cells, or of Chlorella culture filtrate upon growth of larvae of *V. mercenaria*.

Heavy concentrations of food cells in the water usually killed the larvae, but again the lethal concentrations depended upon the size of the food cells. For example, a concentration of about 300,000 cells per cc of large Chlorella cells killed the majority of the larvae within a few days (Fig. 4), while in a concentration of 750,000 cells, total mortality occurred, sometimes within 24 hours. However, concentrations of 750,000 smaller cells per cc will permit survival and growth of the larvae.

Either the algal cells alone or the filtrate only of food cultures or a combination of cells and filtrate may kill the larvae when present in sufficiently high concentration. This can be easily seen in Figure 5, which shows that the cultures receiving food on the basis of 100,000 large Chlorella cells per cc of water grew well (*A*), whereas those receiving either filtered Chlorella cells on the basis of 1,000,000 cells per cc (*D*), or filtrate only, in a quantity that would correspond to that of a culture of 1,000,000 cells per cc (*E*), soon died. It appeared that the concentrated filtrate, containing metabolites of the Chlorella cells, was relatively more harmful than heavy concentrations of the living cells [15]. Apparently the cells in high concentrations interfere with the ciliary activities of the larvae. There is also a chemical effect because of the toxic nature of the metabolic products discharged by the Chlorella cells in the water.

Food Selection and Concentration

Clam larvae show both quantitative and qualitative selectivity in feeding. In heavier than optimum, but still nonlethal concentrations of food cells, the larvae by regulating the amount of food ingested often contained less food in the alimentary tract than did the larvae subjected to lighter food concentrations. This observation suggested that larvae are not merely mechanical feeders but possess a mechanism for controlling the food intake. Nevertheless, if the larvae were kept in a heavy concentration for a long time, this regulating ability was lost and they soon became choked with food cells. When these larvae were removed to clear sea water, they expelled the excess of ingested food and then continued normal development and growth if properly fed. Qualitative selectivity of food was noted when the larvae were fed a mixture of two or three types of food organisms, but gave definite preference to one of them. For example, given a mixture of *Porphyridium* (3 μ) and *Chlamydomonas* (10 μ) the larvae rejected the small cells of *Porphyridium* while ingesting the much larger cells of *Chlamydomonas* [14].

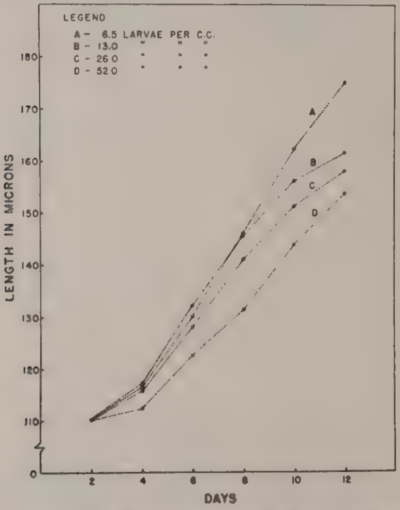

FIG. 6. Mean length of larvae of *Venus mercenaria* of different ages in cultures kept at different population densities but receiving the same quantity of food per cc of water (100,000 cells of large Chlorella).

The question of the concentration of larvae which should be maintained in the culture is an important one. The answer depends to some extent upon the species. A hardy variety of mollusk, such as the hard-shell clam, *Venus mercenaria*, may be started with approximately 50 larvae per cc of water. This may appear to be a much heavier concentration than practiced by other investigators, chiefly Europeans, who usually emphasize the danger of overcrowding. However, since our cultures of such a density were usually carried to metamorphosis, and since on many occasions we have grown successfully even denser cultures, it is clear that the danger of overcrowding the larvae may not be as acute as believed.

In general, the results showed that if the cultures are properly fed, the majority of the larvae will survive the overcrowding and will reach metamorphosis though displaying a slower rate of growth. However, to learn more about the effects of crowding, we decided to conduct a series of quantitative experiments. Davis, keeping oyster larvae in different cultures numbering from 640 to 32,980 per liter, found that the larvae grew in all the cultures but that there was an inverse relation between the concentration of the larvae and the rate of growth. It is interesting that Davis found much greater variations in size in lightly populated, rather than in more dense, cultures [13].

Similar experiments with clam larvae consisted in determining their rate of growth in concentrations of about 6, 13, 26, or 52 larvae per cc and all receiving the same quantity of food, namely, 100,000 large Chlorella cells per cc. The larvae in all cultures reached metamorphosis, but again the mean rate of growth of the different cultures had an inverse relation to the population density (Fig. 6). For example, on the tenth day of larval life the mean length of the larvae in the series of cultures containing 6, 13, 26, or 52 individuals per cc was 162 μ, 156 μ, 151 μ, and 144 μ, respectively. The slower growth of the larvae in the more crowded cultures was probably due in part to more frequent collisions between the larvae, which interfered with their feeding, and in part to the deleterious effects of greater concentrations of excretory products of the larvae accumulating in the culture medium.

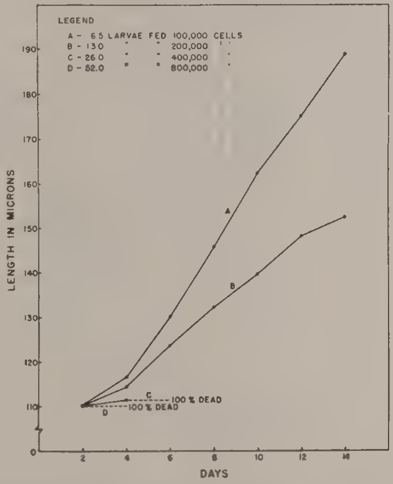

FIG. 7. Effects of increase in food concentrations (large Chlorella) made in proportion to increase in density of larval population upon growth and survival of larvae, *V. mercenaria*.

Another question of interest was whether the rate of growth of the larvae in densely populated cultures could be increased by a proportional increase in the food supply. To solve this problem we conducted an experiment in which the quantity of food supplied to the larvae was increased in proportion to the increase in the larval populations (Fig. 7). The cultures that contained approximately 6 larvae per cc were given 100,000 Chlorella cells per cc per day; the cultures that had 13 larvae per cc received 200,000 cells; 26 larvae per cc received 400,000 cells and the cultures with 52 larvae per cc received 800,000 cells per cc per day.

At the end of ten days, the larvae in the least crowded cultures averaged 162 μ in length, whereas in the cultures with 13 larvae per cc and receiving 200,000 cells of Chlorella per cc the larvae averaged only 148 μ. The larvae supplied with 400,000 cells of Chlorella per cc died within four days, and those given 800,000 cells per cc died within 48 hours. Death, as noted before, was due to lethal concentration of food organisms. Thus, the experiments showed that an increase in the larval population beyond certain limits cannot be compensated for by a proportional increase in the quantity of food supplied.

In certain experiments the larvae, just developed from eggs, were kept in cotton-filtered sea water, receiving no additional food, for as long as 14 days. Naturally their growth was considerably retarded but the larvae continued to swim and remained normal in appearance. If, after this period of starvation, the larvae were given food, they began to grow and eventually reached metamorphosis. It is evident that larvae can endure a starvation diet better than they can overfeeding.

Color in Relation to Food

The study of the cultures shows that the color of the larvae depends to a large extent upon the color of the food they feed on. This was evident in the larvae of several species in almost all stages of development, with the exception of well-developed larvae possessing heavy, thick shells. It seems logical to expect that in nature, where the combination of forms in the plankton changes frequently, correspondingly frequent changes in the color of the larvae may occur. Because of these results we disagree with the workers who maintain that color is one of the dependable criteria for the identification of molluscan larvae [7].

It should also be mentioned in this connection that living larvae can be stained with certain vital stains. Neutral red gave the best results. It is only necessary to keep the larvae in a water solution of neutral red (0.001 gram to one liter) for 30–60 minutes. On transfer to normal culture conditions the larvae are easily recognized by their reddish color for about two weeks or until metamorphosis occurs.

Vital staining offers a new and convenient approach for studying larval behavior under laboratory conditions and also in the field, where vertical and horizontal distribution and dispersal of larvae can be followed, and perhaps even the rates of growth and survival under natural conditions ascertained. The same method, or its variations, may also be used in similar studies of a wide variety of other plankton forms.

Effects of Temperature and Other Culture Conditions

The temperature experiments showed that clam larvae of all stages will grow well within the range of about 18–30°C However, if the eggs are placed in cold water of about 15°C soon after fertilization, virtually none of the eggs will undergo normal development although older larvae will live in water at this temperature. Similarly, if fertilized eggs are placed in water at the high temperature of 33°C a heavy mortality occurs, although larvae two days old and older will grow rapidly at this temperature. These observations show that bivalve embryos in the early cleavage stages require a narrower temperature range than do the later stages.

Within the temperature range of these experiments the larvae generally grew more rapidly at higher temperatures, but small differences of one or two degrees were not so important in affecting the rate of growth as was previously thought, when it was assumed that a difference of only one degree might prolong the swimming period of a larva by several days. Nevertheless, between our extreme temperatures of 18° and 30°C the difference was quite significant because at the lowest temperature the earliest larvae to reach metamorphosis were at least 16 days old, while those kept at 30°C began to metamorphose after 7 days.

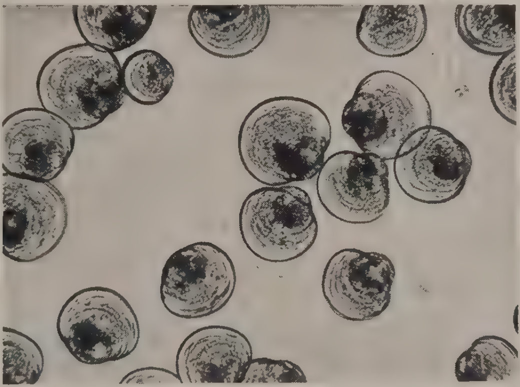

FIG. 8. Difference in sizes of larvae of *Anomia simplex*, 9 days old, which throughout the experiment were kept in the same jar, under identical conditions. (× 112.)

Striking differences were often observed in the sizes of the larvae that came from the same group of clams, sometimes from the same parents, and which were kept under identical conditions in the same culture jar. In the old cultures some of the largest individuals measured approximately 236 μ and were ready to metamorphose, while other larva at this time under the same conditions might be as small as 100 μ. Similar differences in larval size within the same broods were also recorded in *Anomia* (Fig. 8), American, European, and Japanese oysters, small boring clams, razor clams, common mussels, and other species.

As our studies progressed, we began to suspect that the harbor water contained some unidentified substances which largely determine whether cultures of larvae will grow well [3]. This conclusion was reached because of a lack of uniformity in the results of some of the experiments, although identical methods and procedures were employed in all instances and the generally recognized properties of sea water, such as temperature, salinity, and hydrogen-ion concentration, did not vary. However, because these experiments were conducted in succession, during a period of several weeks or even months rather than simultaneously, it was considered possible that the water at various times may have contained different quantities of unidentified substances which affected the development, survival, and rate of growth of the clam larvae. Similar conclusions were reached at about the same time by Wilson [16] working with polychaete larvae and using the water from the Celtic Sea and the English Channel. Davis was faced with the same problem in his nutritive studies on oyster larvae. He suggested that the presence or absence of some unknown factor or factors may affect the ability of larvae to utilize the available food [13].

These substances remain unidentified, but it is clear that complete control of the laboratory experiments involving animals living in sea water requires that the nature of these substances be established. As suggested by Davis, they may be of the same general nature as those reported by Collier, *et al.*, different concentrations of which can be correlated with the quantity of water pumped by adult oysters.

Larval Diseases and Parasites

The field of larval diseases and parasites, virtually closed for any systematic studies until the present methods for growing larvae were developed, should now become an important area for research. Even under the best conditions that can be created in the laboratory there is always some mortality among the larvae —not attributable to the experimental technique—which is probably caused by various diseases or parasites. For example, we often notice weak or dying larvae which are vigorously attacked by ciliates or other microscopic enemies, although we still cannot definitely determine whether these forms are the primary causes of death of the larvae or whether they are merely secondary invaders of sick individuals. There are mortalities that may be caused by bacteria or virus, for which we have already begun using sulfa drugs and antibiotics, and there are diseases now known to be caused by fungi. We shall briefly discuss our experience with the latter.

During a recent heavy mortality in our clam cultures my colleague, Harry C. Davis, noticed in many dead and dying larvae an organism which has been identified as a fungus. Several days later the same or a closely related form was recognized in the larvae of the oyster. Later, en conducting an experiment on hybridization between *V. campechien-* ; and *V. mercenaria*, we found the parasitic fungus in the larvae of *V.* *mpechiensis* and also among the hybrid larvae. The fungus has been ntatively identified as belonging to the genus *Sirolpidium* [17].

It was found that larvae of all ages might be parasitized with this ngus. Moreover, in the clams and probably in other species, even those dividuals that had already metamorphosed were found infested. As a le, soon after infection the larvae stop growing and die. Although the resence of the fungus in our cultures is usually of endemic nature, the isease sometimes acquires epidemic proportions, killing almost the en- re population within a few days.

We believe this is the first observation of a fungus parasite affecting ivalve larvae, and because there are only a few cases known of the oc- urrence of parasitic fungus in salt water species, this discovery appears o be of considerable biological interest. It may also be of economic im- ortance because it is possible that the same or related forms of the ungus cause epidemics among larvae in nature and, therefore, may eriously disrupt the sequence of events in the food chain of the sea, even- ually affecting the survival of different kinds of food fishes. If control methods are found for the most important larval diseases, artificial cultivation of such important commercial mollusks as oysters and clams may become a reality on a large scale.

Summary

Functional methods of growing larvae and later juvenile clams in our laboratory, as described above, are already attracting the attention of economic zoologists. Large numbers of young mollusks, particularly the clam and the European oyster [18], have been grown and supplied to other workers to study the behavior of these bivalves under the different conditions of the new environment.

Finally, the methods developed by us, such as maintaining ripe mollusks for spawning as desired during the late fall and early winter or inducing spawning of the same individual at shorter intervals than it occurs in nature, can surely be applied to many other invertebrates,thus greatly extending the time available for experiments in the North, which are now generally conducted only during the short summer periods.

ACKNOWLEDGMENTS

It is proper to emphasize once more that the methods developed and the results achieved, as described in this article, do not represent entirely my own efforts but are shared by several staff members. Of these my colleague, Harry C. Davis, has significantly contributed to our knowledge of the behavior of larvae, and our laboratory mechanic, Joseph F. Lucash, whose mechanical ability has helped to equip the laboratory with a number of devices, has greatly facilitated our work. I also wish to express my thanks to Charles A. Nomejko for his help in many of the experiments and for the preparation of the illustrations, and to my secretary, Miss Rita S. Riccio, for her help in the preparation and editing of the manuscript.

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U. S. DEPARTMENT OF THE INTERIOR
FISH AND WILDLIFE SERVICE
SEP. NO. 386

December 1954 **Washington 25, D.C.** **Vol. 16, No. 12**

THE 1953 JAPANESE KING-CRAB FACTORYSHIP EXPEDITION

By Takashi Miyahara*

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SUMMARY AND CONCLUSIONS

The 1953 Japanese factoryship expedition for king crabs (Paralithodes camtschatica) in Bristol Bay began operations on April 19, 1953. Fishing was conducted in the vicinity of Amak Island and in the areas north of Port Moller.

The fleet consisted of the factory-mothership, the S. S. Tokei Maru, with 6 small tangle-net boats and 6 trawlers.

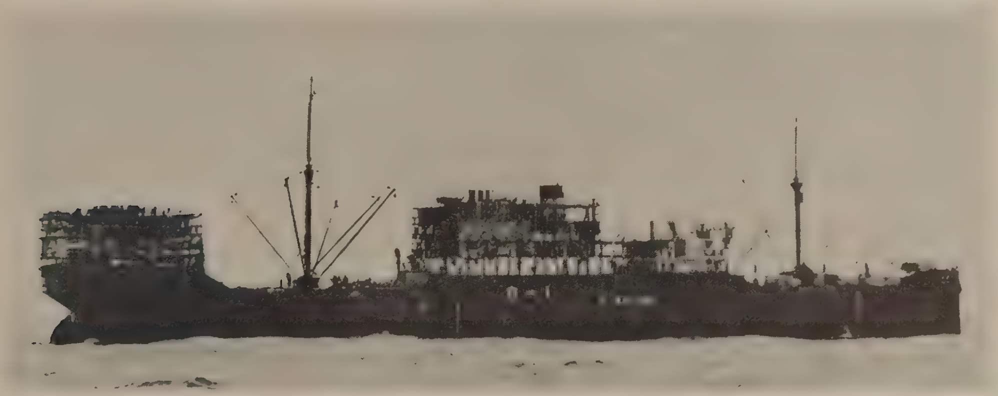

Fig. 1 - The S. S. Tokei Maru, factory-mothership of the 1953 Japanese King-Crab Expedition.

A total of 1,276,360 male king crabs were caught and canned--the pack was 58,240 cases (48 6½-ounce cans) of meat.

The tangle nets accounted for 948,482 male crabs or 74.3 percent of the catch while the trawls caught 327,878 or 25.7 percent.

Two types of trawls were used: (1) the Pacific Coast-type otter trawl and (2) the Danish seine-type trawl.

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* Fishery Research Biologist, Pacific Salmon Investigations, Branch of Fishery Biology, U. S. Fish and Wildlife Service, Seattle, Washington.

The otter trawls were more effective than the seines, taking an average of 84 crabs per hour of drag, while the Danish seines caught an average of 54 per hour.

Typical crab-canning techniques were used for processing the crabs with very few variations, although the acid bath, common in crab canning, was thought to be unnecessary and therefore not used.

Wide variations in the condition of the crabs were observed during the expedition, ranging from soft recently-moulted individuals to barnacle- and weed-covered hard-shell crabs.

Wide variations in weights were also observed.

In view of these variations observed in crabs from different areas, it would appear that there were two or more stocks or age classes represented in the areas exploited, these groups having different moulting periods or intervals.

The female king crabs were observed to moult progressively later in the season as the expedition moved eastward.

The king-crab population in this area appears to be composed almost wholly of Paralithodes camtschatica--only one Paralithodes platypus and no Paralithodes brevipes were observed.

The expedition encountered a large population of tanner crabs (Chionoecetes sp.), especially in the vicinity of Amak Island. This population was thought to be considerably larger than previously observed.

The expedition departed for Japan on August 15, 1953, after 119 days on the fishing grounds.

Because of the nature of the facilities and because observations were conducted in a manner designed to interfere as little as possible with Japanese operations, the observations were limited.

United States and Japanese fishermen felt that this season was not typical or average in regard to weather conditions, localities of crab abundance, and certain other phases of the catch.

It is evident that very little is known about this population of king crabs and the need for better understanding of king-crab biology was expressed by everyone concerned.

KING-CRAB FACTORYSHIP FISHERY

Japanese floating factoryships began catching and canning king crabs in the Bering Sea near Alaska in 1930. Since 1932, operations were continued yearly through 1939 for a total catch during the ten-year period of 7,841,984 crabs which yielded 194,789 cases (96 $\frac{1}{2}$-lb. cans or 48 1-lb. cans) of king-crab meat. The yearly catch and pack of Japanese floating factoryships operated in the Bering Sea are shown in table 1.

During World War II all of Japan's crab-canning factoryships were sunk. In the years following the war their crab fisheries were limited to minor fishing grounds off the northern and eastern coasts of Hokkaido.

Early in 1953 three large fishing firms in Japan made a formal application to the Japanese Fisheries Agency to operate a joint mothership crab expedition to Bristol Bay during the summer. The application was approved, with some modifications, and a catch "target" of 50,000 cases (48 $6\frac{1}{2}$-ounce cans per case) was established. This "target" was later increased to 57,000 cases.

On March 30 of that year, six Japanese trawlers left Hakodate, Japan, as part of this first postwar Japanese crab factoryship fishing and canning expedition in Bristol Bay. Nine days later, the S. S. Tokei Maru, the factory-mothership of the expedition, deckloaded with 6 small fishing boats, departed from the same port, arriving at the fishing grounds approximately 11 miles northwest of Amak Island on April 19, 1953. Fishing was begun immediately upon arrival.

Table 1 - Catch and Pack of Japanese Floating Factoryships in the Bering Sea, 1930-39

Year	Ships Operated	Ship Days Operated	Crabs Caught	Cases Packed 1/
	. . . .	.(Number). . . .	. . . .	. . . .
1939	1	37	241,791	6,206
1938	1	67	461,040	13,385
1937	1	74	485,900	13,148
1936	1	51	290,900	7,849
1935	1	139	746,450	15,504
1934	2	242	1,347,025	30,364
1933	2	289	2,088,998	49,396
1932	1	125	1,178,280	34,365
1931	0	0	0	0
1930	1	95	1,001,600	24,572

1/ One case is equal to 96 $\frac{1}{2}$-lb. cans or 48 1-lb cans.
Note: Information obtained from Japanese Fisheries Agency

To become familiar with this fishery and to initiate a scientific study of this population of crabs, the governments of Japan and the United States agreed to exchange biologists. It was decided that the U. S. Fish and Wildlife Service would place a biologist aboard the Tokei Maru, and the Japanese Fisheries Agency would assign a biologist to the M/V Deep Sea, a United States trawler. It was in this capacity that I accompanied the Japanese expedition from April 19 through August 5, 1953.

Transportation to and from the Tokei Maru and Cold Bay, Alaska, was provided by the trawler M/V Deep Sea through the courtesy of Wakefield's Deep Sea Trawlers, Inc. The hospitality and aid given by the owners, masters, and crew of the Deep Sea are gratefully acknowledged. I wish also to express my sincere thanks to the inspector of the Japanese Fisheries Agency, the various members of the expedition, and to the Nippon Marine Products Company for their hospitality, cooperation, and aid.

SOURCES OF DATA

Observations were made and records kept of various aspects of the Japanese operation, in most cases with the aid of the inspector of the Japanese Fisheries Agency or of various members of the fleet. In this report, I shall describe only the activities connected with the fishing operation, and present later the biological observations.

Crab catches landed aboard the mothership were examined daily, a record being kept of number and condition of the crabs, and of the differences in appearance of crabs from different areas. The tangle-net boats fished relatively close to the mothership and the information on area of catch is fairly accurate. The areas of trawling activity were usually determined by dead reckoning and are subject to some error. The fishing foreman and the fishermen were consulted to determine the area of origin of the crabs caught, and also to determine the amount of fishing effort expended.

Length and width of the carapace and the weights of approximately 3,900 male king crabs (Paralithodes camtschatica) were obtained. Only about 200 female crabs were measured as they were generally released from the catcher boats and their appearance on the mothership was rare. All specimens measured were selected at random, usually from the landings of a single catcher boat in order to accurately determine the area of origin and to minimize interference with the crab handling and processing operations on the factoryships. Specimens of various types have been collected and preserved for later study. Additional observations and records were kept concerning fishing gear and methods, non-king crab forms that were caught, weather and sea conditions, and air and sea temperatures.

FISHING FLEET

The S. S. Tokei Maru, leased from the Towa Steamship Company of Kobe, Japan, was built in the United States in 1919; the length is 401 feet, with a gross tonnage of 4,998 (fig. 1). Navigating equipment consisted of a magnetic compass, radio-direction finder, and loran receiver. However, loran reception was very poor in the area of operation and was further complicated by almost unceasing transmission on the same or on nearby frequencies by the ship's or by the catcher boats' wirelesses. Loran readings were therefore confirmed by sun-sights whenever possible.

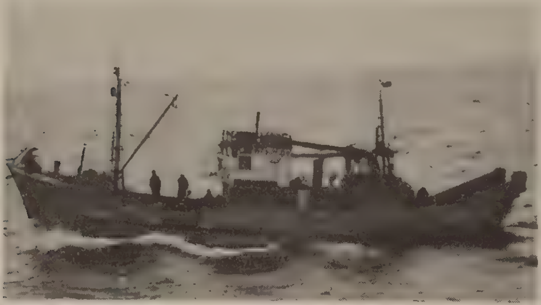


Fig. 2 - A trawler.

The conversion to a factoryship involved the building of temporary wooden platforms on the shelter deck over hatches Number 1, 2, and 4, to give better footing and to provide better drainage as the crabs were piled in these areas prior to processing. The remainder of the shelter deck was partitioned to provide living quarters, dining areas, and gear lockers. The canning equipment, consisting of racks and tables for the meat graders and can fillers, and the clinching, sealing, vacuum, and retort equipment were installed on the upper deck below the shelter deck in the areas of hatches Number 1 and 2. Other conversions included scaffoldings over the bridge and after poop decks to allow for hanging the nets for drying, untangling, and repairing.

A total of 337 men were quartered on the vessel, of which 44 were members of the ship's crew and 54 were fishermen who went out daily on deckloaded boats.

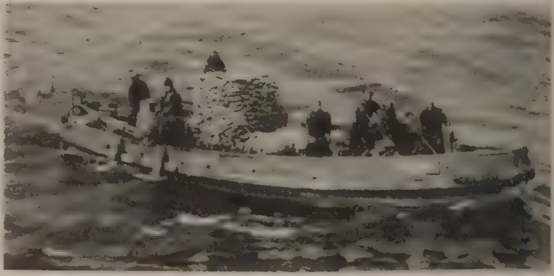


Fig. 3 - A "Kawasaki" boat bringing back a load of tangle net-caught crabs.

The 6 trawlers, 5 of wood construction and 1 of steel, ranged in gross tonnage from 56.48 to 75.43 (fig. 2). They were approximately 90 feet long and powered by Diesel engines of 130 to 210 horsepower. The largest was used in setting tangle nets or in picking up test sets of tangle gear. From time to time, two other trawlers were also used for this work. All were equipped with echo sounders, radio-direction finders, and radio transmitters of about 25- to 50-watt output. Fourteen men lived on each of these vessels for the duration of the expedition, boarding the mothership only on rare occasions for medical treatment, bathing, or other essential needs.

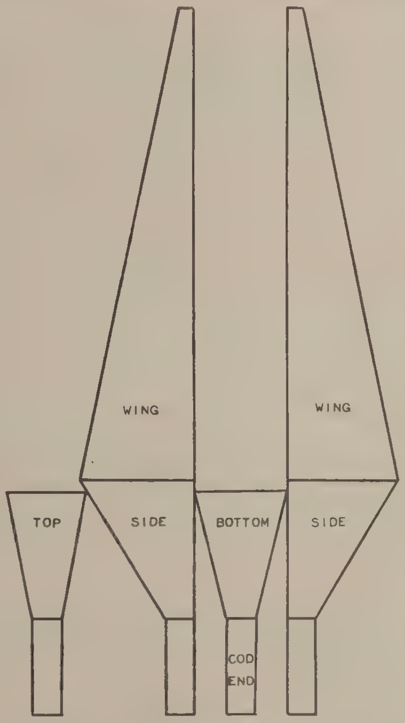
The six deckloaded "Kawasaki" boats which were used strictly for picking up the tangle nets were small vessels approximately 44 feet long and 10 feet in beam, powered with two-cylinder, 15-horsepower engines (fig. 3). The only navigational equipment on these boats was a magnetic compass, but as they were usually within five miles of the mothership, additional navigating equipment was not essential. These boats and their crews of eight men each were lowered from the mothership's davits every day at about 3 a.m. and picked up about 5 to 6 p.m.

FISHING GEAR

The trawls used were of two types; the otter trawl and the Danish seine. Four of the five boats engaged in trawling started the season with the Danish seine, but two of them were converted to otter trawls because of the better successes realized by this method.

OTTER TRAWLS: The otter trawls used were of the Pacific Coast type constructed of manila and cotton. Mesh sizes and other specifications are indicated in figure 4. The otter boards were angled sleds, 1½ by 1 foot on the angle and 5½ feet long. They were constructed of wood, strengthened and weighted with iron reinforcing straps and iron runners. The two one-inch diameter manila ropes used were pulled through two rollers mounted on heavy wooden beams rising above the poop. These ropes were then wound around horizontal gypsy heads on each side of the engine casing, just aft the pilothouse. When the boards were hoisted aboard, the lines from the nets were transferred to the port side, amidships, where they were guided around pulleys and to the capstans. During the period between April 19 and August 3, approximately 1,245 tows were made with this type trawl, averaging two hours per tow and six tows per day.

DANISH SEINES: The Danish seine type of trawling involved laying the net on the sea bottom with the wings spread. When the seine was towed, the wings closed slowly and tended to drive the crabs into the belly of the net. In laying this gear, the starboard tow rope was shackled to a 55-gallon drum buoy, which was then thrown overboard and the rope paid out as the vessel moved away. When approximately one-half of this rope was paid out, the course was changed about 90 degrees to starboard. On this course the remainder of the starboard rope, the starboard wing, and part of the belly were thrown overboard. Another 90-degree turn to starboard was made and on this new course the remainder of the belly, the port wing, and about one-half of the portside tow rope was paid out. The course was again changed in the direction of the buoy, laying out the remainder of the port tow rope.



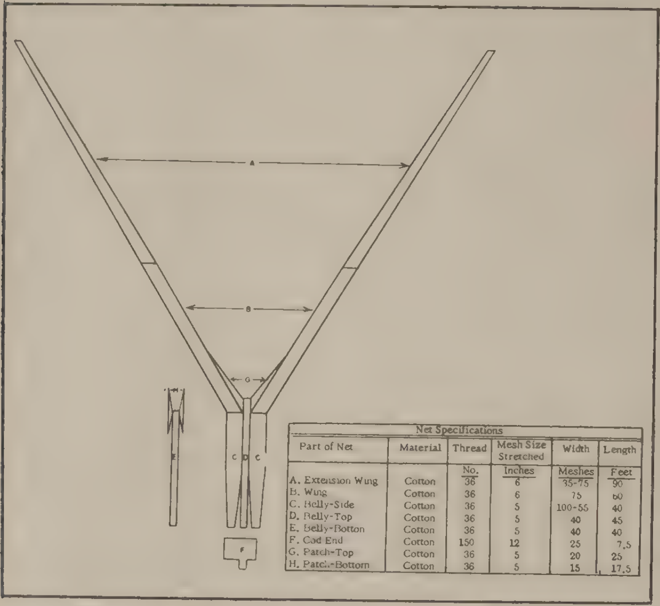
Net Specifications

Part of Net	Material	Thread	Mesh Size Stretched	Width	Length
		No.	Inches	Meshes	Feet
Wing	Cotton	36	6	50	87.5
Sides	Cotton	45	6	50	25
Top	Cotton	45	6	35	24
Bottom . .	Cotton	75	8	30	24
Cod End . .	Manila	6	14	22	20

Fig. 4 - Details of a Japanese king-crab otter trawl.

The buoy was picked up, the two tow lines made fast, and the ship proceeded to tow the net at a very slow speed. The ropes and wings closed slowly. When the tow ropes became parallel, the net was hauled in by pulling the two lines around windlasses. (See fig. 5.).

From April 18 to August 3, approximately 1,100 tows were made with this type of trawl, each tow averaging about 1 hour 40 minutes in duration and each vessel averaging 6.4 tows per fishable day.



Net Specifications					
Part of Net	Material	Thread	Mesh Size Stretched	Width	Length
		No.	Inches	Meshes	Feet
A. Extension Wing	Cotton	36	6	35-75	90
B. Wing	Cotton	36	6	75	60
C. Belly-Side	Cotton	36	5	100-55	40
D. Belly-Top	Cotton	36	5	40	45
E. Belly-Botton	Cotton	36	5	40	40
F. Cod End	Cotton	150	12	25	7.5
G. Patch-Top	Cotton	36	5	20	25
H. Patch-Bottom	Cotton	36	5	15	17.5

Fig. 5 - Details of a Danish seine used for fishing king crabs.

All trawl and seine catches were dropped on the deck where they were sorted. The undersize and female crabs, together with the scraps, were thrown overboard and the males butchered.

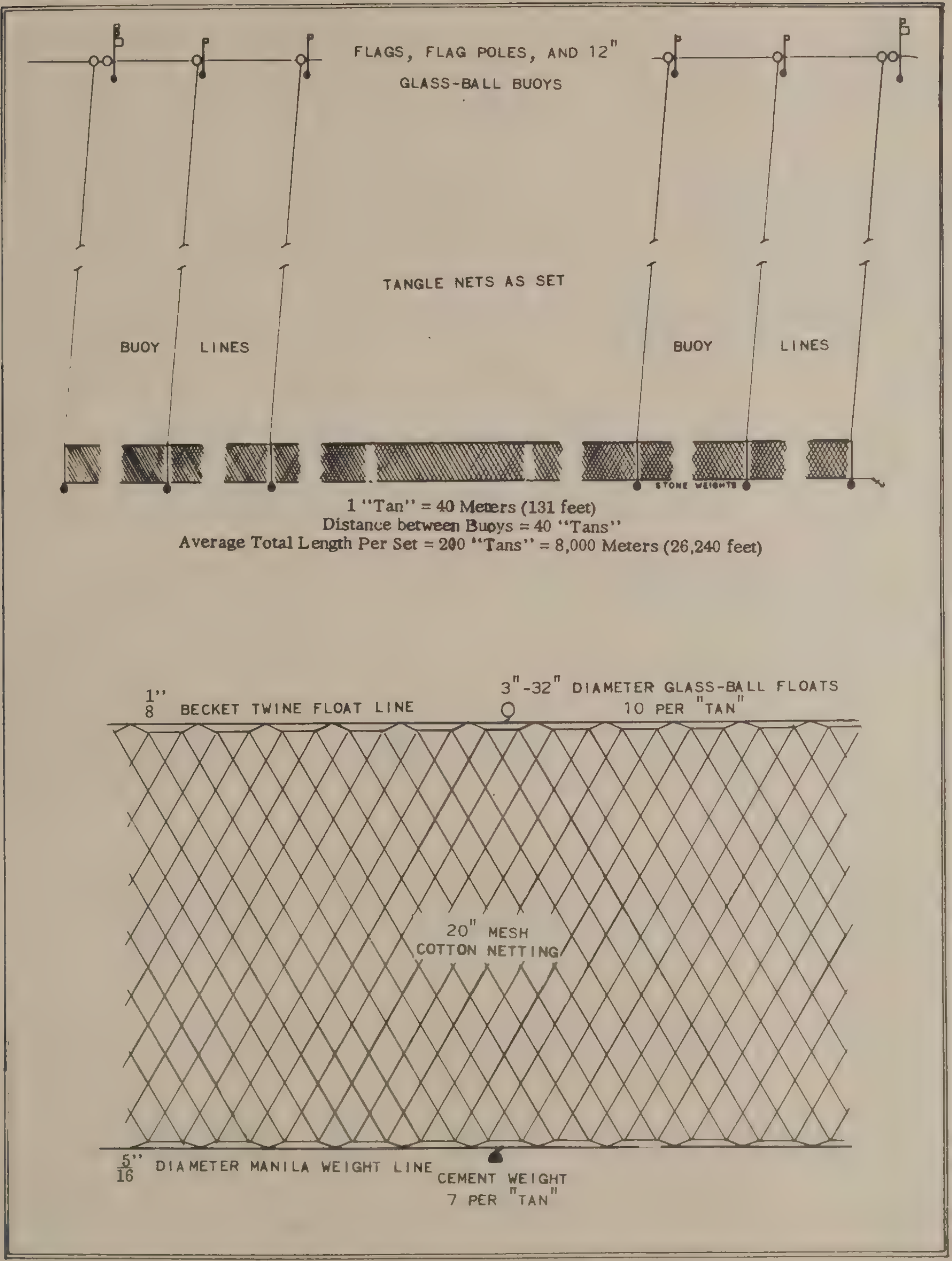
TANGLE NETS: The tangle nets (fig. 6) employed by this crab expedition were cotton netting, 18-inch stretched mesh, 7 meshes deep, hung between a $\frac{1}{8}$-inch becket twine float line, and a 6-thread $\frac{5}{16}$-inch manila lead line. The floats used were glass balls 3 to 3.2 inches in diameter and the weights were cement balls weighing about two pounds each. Ten glass balls and seven weights were tied to each "tan" (shackle) of net.

These nets were made up in "tans," 40 meters (131 feet) in length. Approximately 200 of these "tans" were tied end-to-end for each set. Each set was anchored at both ends by kedge anchors and marked with flags held in place by two glass buoys 10 or 12 inches in diameter. At intervals along the set, usually 1,600 meters (5,248 feet), glass buoys and flags were attached. Each set was distinguished from another by the color of the flag and by small wooden tags tied to the poles. The wooden tags indicated the date of the set and the boat from which the particular set was made. Sets were made parallel to each other at distances of 100 to 300 meters (328-984 feet).

An average of 941 "tans" of tangle net were picked up per fishing day. Depending upon the estimate of the size and quality of a school of crabs, from 3,000 to 14,000 "tans" were fished. The average number of "tans" left in the water per day was 6,209.

Because the current in the areas flowed southwesterly and northeasterly, all sets were made in the same direction to prevent the drifting of one set against another. All sets were made by one of the trawler-type boats which sailed in a northeasterly or southwesterly direction at a speed of about 6 knots, while 6 to 9 men on the afterdeck tied the glass balls and cement weights to the netting and threw it overboard.

After the tangle nets were fished from 5 to 10 days, "Kawasaki" boats were dispatched to pick them up. For the most part, the crabs were disentangled on the "Kawasaki" boats, and all but the larger male king crabs were thrown immediately overboard. On several occasions, the nets, with crabs entangled, were brought to the mothership where a group of laborers was assigned to disentangle them.


FLAGS, FLAG POLES, AND 12" GLASS-BALL BUOYS
TANGLE NETS AS SET
BUOY LINES
BUOY LINES
STONE WEIGHTS
1/8" BECKET TWINE FLOAT LINE
3"-32" DIAMETER GLASS-BALL FLOATS 10 PER "TAN"
20" MESH COTTON NETTING
5/16" DIAMETER MANILA WEIGHT LINE
CEMENT WEIGHT 7 PER "TAN"

1 "Tan" = 40 Meters (131 feet)
Distance between Buoys = 40 "Tans"
Average Total Length Per Set = 200 "Tans" = 8,000 Meters (26,240 feet)

Fig. 6 - Details of tangle nets used for king-crab fishing.

FISHING AREAS AND CATCH

The areas fished by this operation are indicated on figure 7, showing a movement from the area north of Unimak Island, eastward to areas north of Port Moller. The areas noted on the figure are primarily of tangle-net fishing because of the more accurate positions obtainable.

Productive tangle-net fishing areas were found by one of two methods. (1) Trawler catches were examined to locate areas showing an abundance of male king crabs with absence or very small numbers of other forms. (2) Tangle nets were set over great distances for periods of one day to determine abundance and composition of catch. Catches per set were carefully noted and areas where good catches were made were lined with tangle nets on the same or on the following day. Because tangle-net fishing involves a great deal of time-consuming labor, the prime consideration in determining the fishing area for this gear was that of the composition of the catch. Therefore, areas of king-crab abundance were sometimes avoided when large numbers of tanner crabs (Chionoecetes sp.) or other undesirable forms were present.

The condition of the crabs was a prime consideration because crabs in four general stages were encountered by both the trawls and the tangle nets at various times during the season. These conditions include soft-shell crabs and three stages of hard-shell crabs. The meat from soft-shell crabs was undesirable because of the lack of weight and poor texture. The other undesirable condition was found in old-shell crabs, which were light in weight. The meat from these crabs was stringy, discolored, and crumbled quite easily. The desirable crabs were the heavy ones with hard carapaces. Crabs in this condition were of two types: those recently moulted and those which apparently had not moulted for some time.

Table 2 - Catch and Pack by Areas--1953 Japanese Factoryship King-Crab Operations in the Bering Sea

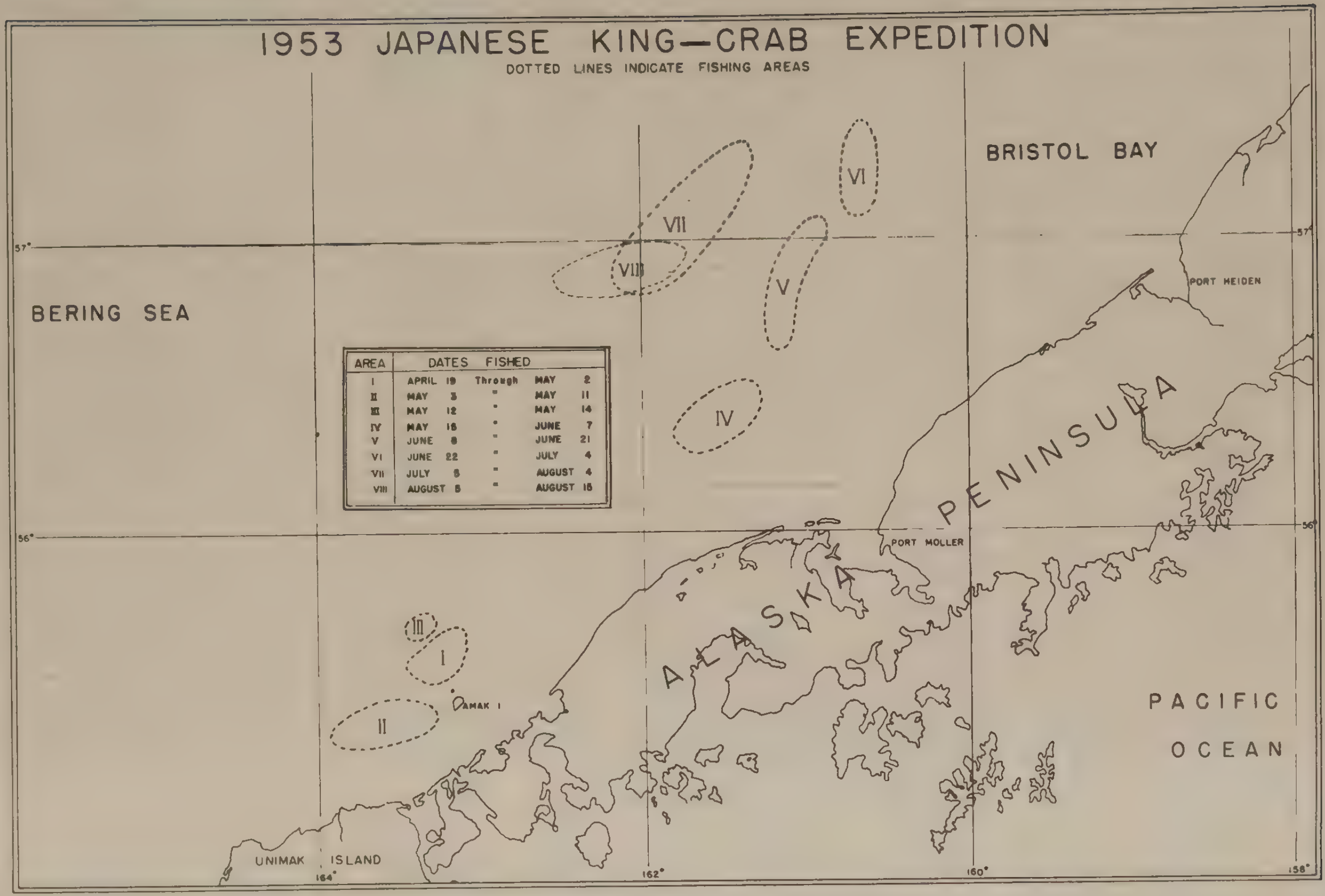
			Tangle Nets			Danish Seines and Otter Trawls				Pack		
Area	Date	Days Fished	Tans Pulled	Catch	Catch Per Tan	Drags	Catch	Catch Per Drags	Total Catch	Grade I	Grade II	Total
	Mo./Day	. . . .	. . (Number)	. . . .	. . . .	. . . .	. . . .	. . . .	. . . .	(Number of Cases 1/)		
I	4/19-5/2	12	8,227	34,296	4.17	194	10,976	56.6	45,272	2,186	451	2,637
II	5/3-5/11	9	10,150	26,295	2.59	147	4,066	27.7	30,361	1,534	305	1,839
III	5/12-5/14	3	4,009	22,915	5.72	67	1,861	27.8	24,776	853	237	1,090
IV	5/15-6/7	22	18,440	212,663	11.53	561	85,622	152.6	298,285	12,966	3,705	16,671
V	6/8-6/21	14	12,178	121,258	9.96	279	46,709	167.4	167,967	6,925	1,459	8,384
VI	6/22-7/4	13	8,954	135,773	15.16	367	37,949	103.4	173,722	6,716	1,356	8,072
VII	7/5-8/4	30	32,260	297,996	9.24	755	121,782	161.3	419,778	12,275	2,054	14,329
2/	8/5-8/15	11	12,087	97,286	8.05	164	18,913	115.3	116,199	4,403	815	5,218
Totals		113	106,305	948,482	8.92 (Avg.)	2,534	327,878	129.4 (Avg.)	1,276,360	47,858	10,382	58,240

1/ Each case contains 48 6½-ounce cans.
2/ These data were collected and reported by the Japanese Fisheries Agency.

Areas showing large numbers of undesirable crabs were avoided. If, however, the numbers were not too great, the crabs were caught and the meat mixed with the better grades of meat to produce a satisfactory pack.

Areas I, II, and III were fished from April 19 through May 14. The first tangle nets were not raised until April 22. The catch during this period was poor because of the presence of large numbers of tanner crabs and very few king crabs. Catches of over 100 tanner crabs per "tan" of tangle net were often made. The tanner crabs were destructive to the netting, and it was difficult and time consuming to disentangle them.

In April the eggs carried by the female crabs were brown in color and the eyes of the developing larvae could be seen. As the season progressed, there was a noticeable decrease in the number of eggs carried, presumably due to the eggs hatching. On these crabs new, soft, but well-formed shells could be observed under their


1953 JAPANESE KING—CRAB EXPEDITION
DOTTED LINES INDICATE FISHING AREAS
BRISTOL BAY
BERING SEA
PACIFIC OCEAN
ALASKA PENINSULA
PORT HEIDEN
PORT MOLLER
AMAK I
UNIMAK ISLAND
I
II
III
IV
V
VI
VII
VIII
57°
56°
164°
162°
160°
158°

AREA	DATES	FISHED		
I	APRIL 19	Through	MAY	2
II	MAY 3	"	MAY	11
III	MAY 12	"	MAY	14
IV	MAY 15	"	JUNE	7
V	JUNE 8	"	JUNE	21
VI	JUNE 22	"	JULY	4
VII	JULY 5	"	AUGUST	4
VIII	AUGUST 5	"	AUGUST	15

Fig. 7 - Map showing king-crab fishing areas.

old carapaces, indicating an approaching moult. This condition was especially prevalent in Area II, southwest of Amak Island.

Area IV, fished from May 15 through June 7, was an area of large, old-shell, heavy males, including a comparatively high percentage of barnacle-encrusted crabs, most of which were well covered with algae and weed growths. The fishing was very good during the 21 fishable days in this area, and a total of 298, 285 male crabs was taken. Of these, 212, 663 were taken with tangle gear and the remainder of 85, 622 by the trawls.

The females in Area IV did not show signs of approaching a moult until May 20, when one female was observed with fewer eggs than normal. From this date, there was an increase in the number of female crabs which were losing their eggs or in which the formation of new shells was evident under the old carapaces.

On May 25 there was an increase in the tangle-net catch of recently-moulted but heavy male crabs. These crabs had clean hard shells and, though not as heavy as the older-shell crabs, were in good canning condition. The increase in this type of crab continued only for a few days and never in this area comprised more than 10 percent of the catch.

In Area V there was wide diversity in the condition of the crabs. From June 8 through June 14, the catch was composed almost entirely of old-shell heavy crabs with a sprinkling of just-moulted heavy crabs. However, on June 15 and 16 there was an increase in the tangle-net catch of crabs that were dirty, barnacle covered, and very light in weight. The meat from these crabs was discolored and therefore undesirable. The catch from June 17 through June 21 had very few low-grade crabs and showed an increase of recently-moulted but hard-shell heavy crabs. The catch in this area was generally good. During the 14 fishable days in Area V, a total of 167, 967 male crabs were caught, 121, 258 by tangle gear and 46, 709 by trawls.

Most of the females observed during this period were found to be practically void of eggs and an increasing number of soft-shell females was evident. On June 20 the first female having newly-deposited purplish-black eggs was seen.

The catch in Area VI was very similar to that in Area V. The catch of June 24 and 25 was of the old-shell light-weight condition, whereas the catch on other days was of good heavy crabs. There was, however, an increase in the recently-moulted males. The trawlers' catches were often composed almost wholly of recently-moulted crabs. Most of these were in fair condition in regard to weight but were noticeably smaller than average. On June 27 the tangle nets showed their most efficient day with an average catch of 30.4 crabs per "tan" as compared with the overall average of 8.92 per "tan."

The females taken in this area were for the most part all moulted, with some having partially-hardened shells. Those with hardened shells all had the typical dark-colored newly-deposited eggs.

Area VII produced a large number of recently moulted crabs, and though they had fairly hard shells they still had not reached the heavy condition. The tangle nets tended to catch a larger percentage of the harder-shell forms, but even with this gear, the catch of recently-hardened but light-weight crabs often made up 60 percent of the day's catch. The trawl catches during this period (July 5 through August 4) were occasionally composed entirely of king crabs in this stage. The utilization of the crabs, based on the number of crabs required to produce one case of canned crab meat, was the poorest during this period. It took approximately $1\frac{1}{2}$ times as many crabs to produce one case in Area VII as was required in Area IV.

During this period females were reported to be in fewer numbers and were almost always of the new-shell form with newly-attached dark-colored eggs. Catch and pack data by areas are shown in tables 2 and 3.

Table 3 - Daily Catch and Pack--1953 Japanese Factoryship King-Crab Operations in the Bering Sea

Date	Catch			Pack		
	Tangle Nets	Trawls	Total	Grade I	Grade II	Total
	. . . (Number of Crabs) . . .			. (Number of Cases 1/).		
Apr. 19	0	560	560	0	0	0
" 20	0	1,400	1,400	28	0	28
" 21	0	1,016	1,016	45	25	70
" 22	2,594	2,525	5,119	79	24	103
" 23	5,444	1,836	7,280	404	80	484
" 24	3,441	303	3,744	264	47	311
" 25	0	0	0	165	36	201
" 26	1,978	339	2,317	0	0	0
" 27	0	127	127	122	20	142
" 28	0	0	0	0	0	0
" 29	4,435	692	5,127	136	23	159
" 30	7,338	885	8,223	300	57	357
May 1	5,291	786	6,077	384	73	457
" 2	3,775	507	4,282	259	66	325
" 3	2,593	782	3,375	97	26	123
" 4	1,362	0	1,362	162	56	218
" 5	3,065	762	3,827	83	16	99
" 6	3,063	594	3,657	186	42	228
" 7	3,162	614	3,776	192	39	231
" 8	2,511	228	2,739	187	29	216
" 9	3,358	392	3,750	140	19	159
" 10	3,786	389	4,175	212	25	237
" 11	3,395	305	3,700	275	53	328
" 12	5,566	237	5,803	90	24	114
" 13	7,037	404	7,441	388	92	480
" 14	10,312	1,220	11,532	375	121	496
" 15	3,787	320	4,107	315	100	416
" 16	0	0	0	179	76	255
" 17	12,764	2,158	14,922	215	97	312
" 18	11,056	3,015	14,071	526	190	716
" 19	10,838	4,679	15,517	592	176	768
" 20	4,509	4,254	8,763	845	209	1,054
" 21	7,821	2,363	10,184	473	155	628
" 22	13,641	2,847	16,488	714	222	936
" 23	6,743	4,137	10,880	459	99	558
" 24	5,941	6,192	12,133	525	122	647
" 25	9,617	5,147	14,764	640	152	792
" 26	8,387	5,623	14,010	522	148	670
" 27	5,833	3,072	8,905	465	92	557
" 28	12,734	1,829	14,563	500	143	643
" 29	12,813	2,922	15,735	579	97	676
" 30	0	307	307	370	196	566
" 31	10,010	3,301	13,311	234	92	326
June 1	13,384	4,640	18,024	651	253	904
" 2	14,286	4,722	19,008	730	291	1,021
" 3	10,150	5,221	15,371	742	173	915
" 4	13,403	2,490	15,893	695	160	855
" 5	10,046	2,923	12,969	676	171	847
" 6	8,846	7,123	15,969	651	150	801
" 7	6,054	6,337	12,391	667	141	808
" 8	8,053	1,515	9,568	478	98	576
" 9	7,514	1,050	8,564	441	85	526
" 10	10,563	735	11,298	433	93	526
" 11	6,015	680	6,695	349	108	457
" 12	11,121	4,316	15,437	509	121	630
" 13	9,407	4,131	13,538	690	138	828
" 14	5,401	7,568	12,969	388	62	450
" 15	1,982	0	1,982	441	52	493
" 16	4,786	8,377	13,163	156	38	194
" 17	5,830	8,345	14,175	534	117	651
June 18	3,282	3,282	11,914	662	150	812
" 19	12,848	0	12,848	546	125	671
" 20	14,335	2,661	16,996	642	153	795
" 21	14,771	4,049	18,820	656	119	775
" 22	5,068	3,566	8,634	668	101	769
" 23	16,590	3,640	20,230	520	123	643
" 24	13,934	3,884	17,818	742	154	896
" 25	12,274	3,090	15,364	681	157	838
" 26	8,993	1,471	10,464	518	82	600
" 27	13,836	3,118	16,956	549	119	668
" 28	12,880	2,677	15,557	660	109	769
" 29	7,823	2,696	10,519	411	65	476
" 30	9,529	2,156	11,685	358	77	435
July 1	11,511	3,124	14,635	501	117	618
" 2	8,844	2,025	10,869	409	73	482
" 3	10,015	2,989	13,004	361	93	454
" 4	4,474	3,513	7,987	338	86	424
" 5	5,364	4,069	9,433	272	59	331
" 6	3,275	5,988	9,263	191	21	212
" 7	13,194	3,207	16,401	532	41	573
" 8	11,842	2,782	14,624	630	54	684
" 9	9,965	3,081	13,046	459	50	509
" 10	9,167	5,006	14,173	484	60	544
" 11	14,121	3,641	17,762	461	61	522
" 12	14,261	2,909	17,170	561	88	649
" 13	14,309	3,686	17,995	423	94	517
" 14	14,758	4,257	19,015	448	133	581
" 15	15,242	4,198	19,440	507	119	626
" 16	10,114	6,821	16,935	495	131	626
" 17	10,907	8,885	19,792	382	112	494
" 18	9,299	8,847	18,146	559	94	653
" 19	12,755	4,452	17,207	456	33	489
" 20	10,282	3,163	13,445	457	76	533
" 21	3,313	4,120	7,433	103	13	116
" 22	10,900	4,445	15,345	339	64	403
" 23	11,173	4,066	15,239	499	86	585
" 24	14,817	2,902	17,719	405	65	470
" 25	18,114	1,607	19,721	482	90	572
" 26	11,065	3,072	14,137	468	79	547
" 27	12,735	3,806	16,541	452	72	524
" 28	8,134	4,128	12,262	444	69	513
" 29	6,691	5,773	12,464	380	61	441
" 30	3,980	3,552	7,532	408	51	459
" 31	4,947	4,486	9,433	232	38	270
Aug. 1	7,340	3,449	10,789	391	68	459
" 2	0	0	0	197	31	228
" 3	2,118	511	2,629	80	21	101
" 4	3,814	873	4,687	78	20	98
" 5	3,525	0	3,525	84	19	103
" 6	11,585	1,783	13,368	370	69	439
" 7	11,515	3,156	14,671	424	83	507
" 8	10,213	3,354	13,567	503	115	618
" 9	9,667	3,202	12,869	496	112	608
" 10	10,528	3,438	13,966	512	109	621
" 11	7,705	3,980	11,685	477	129	606
" 12	9,710		9,710	478	103	581
" 13	10,461		10,461	486	76	562
" 14	8,327		8,327	438	0	438
" 15	4,050		4,050	135	0	135
Totals	948,482	327,878	1,276,360	47,858	10,382	58,240

1/ Each case contains 48 6½-ounce cans.

PROCESSING

The tangle-net crabs were brought to the mothership as soon as the small boats were loaded or after a set had been entirely picked up. Each of these boats usually made two trips to the mothership daily whereas the trawlers kept their catch until about 6 or 7 p.m., the end of the fishing day. As soon as a load of crabs was hoisted onto the temporary platform above Number 4 hatch, a crew of 10 to 20 men butchered them by stepping on the triangular-shaped abdomen on the ventral side of the crab and pulling up on the legs (fig. 8), thus separating the leg and body from the carapace and the viscera, which were immediately thrown over the side. The legs with the attached body meat were thrown into bags made of heavy netting which were then transferred from the butchering area to the cooking pots located on hatch Number 2.

In the transferring operation, a winch was employed to drop the bags overboard after they were secured to a line from a winch at Number 2 hatch. As the bags were pulled through the water on the starboard side of the ship, much of the viscera which may have clung to the legs was washed off. The bags with their load of crab legs were then lifted out of the water at hatch Number 2 and placed into one of three large steel vats (5.1 feet on each side and 6 feet deep) mounted by the starboard railing. The vats were filled with sea water and kept hot by a coil of copper steam pipes graduated from 2 to $1\frac{1}{2}$ inches in diameter on the bottom of each vat. The crabs were cooked in the vats for a period of 20 to 25 minutes, after which they were again lowered into the sea to cool for about 7 to 8 minutes.

The next step in the processing of the crabs was to separate all the legs and to remove the major chela: the chelae were kept separate and counted as a check on number of crabs being processed. The legs were then cut at the joints and the meat shaken out and placed into straw baskets which were dipped twice in brine to wash off coagulated blood and bits of shell. The acid bath, common in crab canning, was deemed unnecessary when the cooked crab had been washed thoroughly. The baskets of meat were then passed below deck where they were graded and cut to the desired lengths. A prescribed quantity of each type of meat, such as chela meat, body meat, merus meat, etc., was then weighed and placed in plastic plates which were distributed by runners to other workers who put the meat from each plate into a "C enameled" can lined with parchment. Runners then carried tray loads of the filled cans to a spot inspection table, where they were inspected for weight, fill, and appearance. From this table the cans proceeded on a chain belt to the clincher, seamer, and vacuum machines, and finally to the retorts.

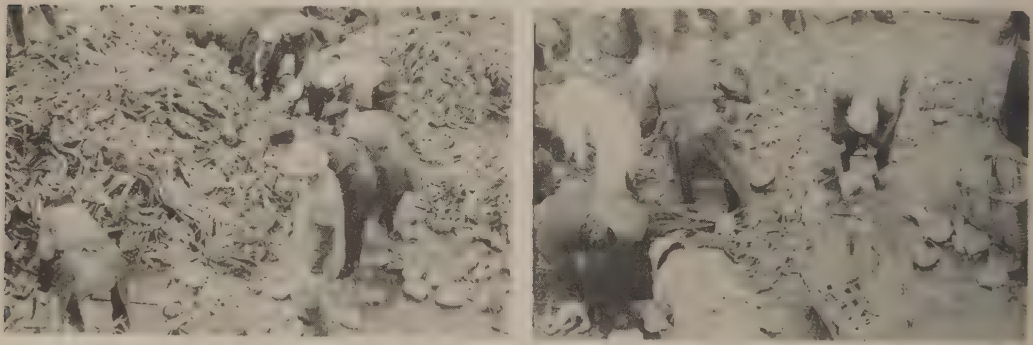


Fig. 8 - Views of butchering platform showing workers butchering crabs by stepping on the abdomen and pulling the legs.

Fisheries Knowledge Increased Through Research Vessel

By
JAMES W. MOFFETT
U. S. Fish and Wildlife Service

CISCO
U S FISH-WILDLIFE SERVICE
CISCO
FWS-17

U. S. Fish and Wildlife Service Research Vessel
CISCO

FISHERIES KNOWLEDGE INCREASED THROUGH RESEARCH VESSEL

By
Dr. James W. Moffett,
U. S. Fish & Wildlife Service

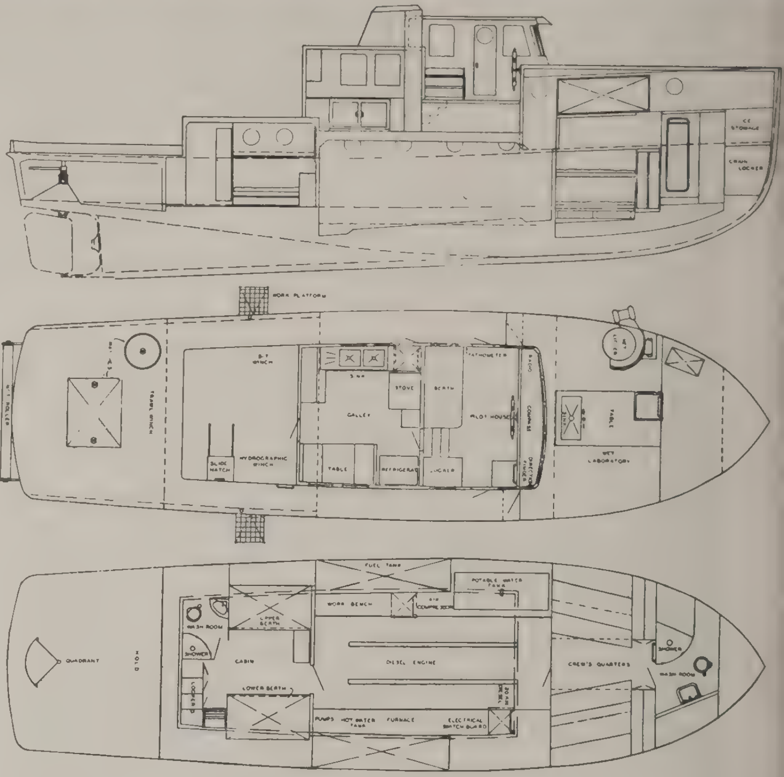
●

Nothing is more frustrating to persons interested in fishery and limnological problems than the helplessness that confronts them when no facilities are available for getting at the heart of a problem. Without such facilities, research programs can provide only indirect approaches and, at times, important phases of a well-balanced study are unavoidably neglected. Fishery research and limnological studies on the majority of the Great Lakes have always been handicapped by a lack of vessels and equipment.

A research vessel, the *Fulmar,* was available to the Great Lakes Fishery Investigations of the U. S. Fish and Wildlife Service for three seasons in the early 1930's. This vessel was used almost exclusively on an emergency project to determine the proper mesh sizes for chub gill nets in Lake Michigan. Much of the support for the *Fulmar* operation came from the States of Michigan and Wisconsin and from netting manufacturers. As soon as the problem was explored and answers obtained, the study was stopped. Despite the short period of vessel operation, much information was obtained. Materials collected and observations made during these campaigns have been the basis of numerous research reports which have contributed much to our knowledge of the fish and fisheries of Lake Michigan.

The course of Great Lakes fishery research by the Fish and Wildlife Service has been determined almost exclusively by the extent or rather the lack of facilities. Problems were selected which required little or no equipment and a minimum of field operations. Great dependence upon the commercial fishermen and their catches for specimens and for other information characterized the research effort for about a quarter-century. Fish obtained from the fishermen were limited generally to sizes normally caught in commercial gear and juvenile stages were seldom available. The details of many important early life-history stages of our more valuable species had to be deduced from adult specimens. Limnological observations were practically non-existent.

An adequately equipped research vessel was one of the first items considered necessary to the Great Lakes Fishery Investigations as the study of lake trout rehabilitation and the development of sea lamprey control methods were undertaken. The need for floating equipment was recognized in practically all approaches to the sea lamprey problem and to other associated fishery and limnological investigations. Preliminary plans for such a vessel were formulated in the later months of 1949.



Contacts with naval architects familiar with construction of Great Lakes ships resulted in the commissioning of Mr. Walter Haertel of Sturgeon Bay, Wisconsin, to design a vessel and supervise its construction. With assistance from the staff of Great Lakes Fishery Investigations, Mr. Haertel drew plans and wrote specifications which were approved by the Fish and Wildlife Service. These specifications formed the basis for bid solicitations in June 1950.

The contract for construction was awarded to Peterson Builders, Inc., Sturgeon Bay, Wisconsin and work was started in early July 1950. The outbreak of hostilities in Korea delayed construction and handicapped procurement of materials so much that the vessel was not launched until November 1950. Finishing, equipping and testing before delivery required the remainder of the winter and all of the following spring. The vessel was accepted by the Government and christened, *Cisco*, on June 6, 1951. At the time of acceptance the total cost of the vessel was $76,334. This amount includes architect's fees and expenses.

The *Cisco* has an all-steel, welded-construction, V-type, square stern hull, 60.5 feet in length over-all, 58.33 feet in length at the waterline, 17.83 feet in beam over fenders and 16.75 feet in beam molded at the main deck. Her depth molded is 8 feet; her draft molded (mean load) is 4.5 feet amidships, and 6.5 feet aft.

The *Cisco* is powered by a Murphy Diesel engine (Model 170) capable of 170 HP at 1200 RPM. Two accessory diesel engines drive electrical generating units — one a 3 KW (Fairbanks-Morse) standby and the other a 20 KW (Caterpillar) main plant. The electricity (110-220 V., AC three-phase) operates an air compressor, blowers, water pumps, a hot-water oil furnace, refrigerator, freezer, lighting system, water heater, various sump and bilge pumps, two hydrographic winches, and scientific and navigational equipment aboard. Shore connections are provided for use while at dock. Matched fuel tanks, of 800-gallon capacity each; occupy the sides of the engine room. Tool racks, a work bench, and a portable water tank of 400-gallon capacity are located on e port side. An intercommunication stem provides contact between all rts of the vessel and insures coordi- tion of effort between the pilot use, engine room, lifter station, and e winches on the afterdeck.

The *Cisco* can accommodate nine rsons. Quarters for the four-man ew are in the forecastle and for four ologists in the after cabin. Quarters r one man, usually the captain, are the pilot house. Each of the quar- rs below decks is provided with ash-room and shower. The arrange- ent of deck, galley, and pilot-house aces is best illustrated by the accom- anying line drawings. The forward ortion of the boat is covered with a turtle deck" under which are located Crossley net lifter, a sink, metal ble, sharp freezer, racks for instru- ents, panels for recording devices, e and chain lockers, and storage ace for other items. The after deck open to accommodate trawling gear, cientific equipment, and gill nets and provide for efficient operation of he trawl winch (Hathaway double rum) and the two hydrographic inches (U. S. Navy design.) Be- eath the afterdeck is a spacious stor- ge hold in which gear and equipment an be stowed. The stern is provided ith a wide roller for easy, free hand- ing of trawls, seines, and gill nets. A ast and boom for net handling, gen- ral loading and unloading, and as a upport for cables and lines used in ervicing trawls is provided amidships ust aft of the galley and atop the fterquarters trunk.

The pilot house is equipped with agnetic compass, gyro-compass, adio-direction finder, sonic depth re- order, ship-to-shore telephone, record- ng microbarograph, barometer, and adar. The usual searchlight, horn, and avigational lights are provided, with ontrols for all within easy reach of he helmsman.

The galley is furnished with an oil- urning, marine-type stove, ample upboard and storage space, stainless teel sink and drainboards, electric re- rigerator, electric coffee makers, oaster, and other accessories. Four persons can be seated at the galley table at one time. The Service has found it most satisfactory to operate the mess and to supply a cook as part of the crew.

Fishing equipment aboard the *Cisco* consists of all-nylon gill nets ranging in mesh size from 1 inch through 6 inches (stretched measure) in ½-inch and, in some sizes, ¼-inch intervals, several types of experimental trawls, bull nets, boxes, slings, buoys, and anchors. The bottom trawls are modeled after the shrimp trawls used in the Gulf of Mexico. A midwater trawl, similar to one developed by Scripps Institution of Oceanography, has been built and fished but has taken few fish.

Limnological apparatus includes bathythermographs of 200-, 450-, and 900-foot depth ranges. These ingenious devices make a vertical record of water temperature while the vessel is under way. Electrical resistance thermometers are used to check surface-water temperatures. One of these thermometers records constantly the temperature of surface waters whenever the vessel is under way. Clarke-Bumpus metering plankton nets with bags of three different mesh sizes are available. Nansen water-sampling bottles equipped with Negretti-Zambra deep-sea reversing thermometers are used to collect water from different depths. These water samples are checked immediately for gaseous content; portions are bottled in glass containers for mineral analysis and other portions are quick-frozen in plastic bottles for subsequent analysis of nitrogen, phosphorous, and organic content. Water samples are transported to the Ann Arbor, Michigan, headquarters laboratory where colorimetry and spectrophotometry are employed in their chemical analysis. Three types of bottom samplers are available for use in obtaining samples of the bottom for studies of composition and bottom organisms. The Ekman, Peterson, and Orange-peel dredges aboard, each serves a special purpose in our studies of bottom sedimentation and biological production. The vessel also carries matched photometers capable of measuring the depth of penetration of different colors of light into the lakes. Other equipment includes water current meters, plastic-covered drift cards, and miscellaneous small apparatus.

This well-equipped research vessel on the Great Lakes has provided, and will continue to provide, answers to many problems in addition to those related to the sea lamprey.

With the *Cisco's* facilities, we have come a long way toward learning the habits of the lake trout and its associates. Such knowledge is essential if we are to do a good job of lake trout rehabilitation, once the lamprey is under control. We need and are obtaining intimate knowledge of fish other than those exploited by the fisherman. We hope to learn the abundance, age composition, and habits of commercial species before they reach a legal size so that we can prepare fishermen in advance for some of the fluctuations in catch which often mean poverty or prosperity to them. The *Cisco* is enabling us to learn the inner workings of the lakes and their influence in producing sudden abundance or scarcity of fishes. There are countless questions which the vessel will help us answer.

Uninterrupted and efficient operation of the *Cisco* will contribute, and is contributing, many facts in such matters as: artificial *vs.* natural production, migrations of fishes, causes of big and little year classes, overfishing, rates of stock replacement, reasons for growth - rate changes, production trends, effects of existing regulations, requirements of proper regulations, feeding habits of fish, predator-prey relationships, interrelationships between fish species, fish-food production changes, the true role of smelt and other introduced species, new and efficient types of fishing gear, and many other real issues. These pressing questions, important to all of us, can be answered with the evidence obtained from effective operation of a research vessel and with the genuine cooperation of all persons interested in the Great Lakes.

[Reprinted from THE FISHERMAN, Vol. 22, No. 3, Spring, 1954, pp. 7 and 13-14]
[The Photograph of the CISCO Appeared on the Front Cover of This Issue]

EXTRAIT DU JOURNAL DU CONSEIL INTERNATIONAL
POUR L'EXPLORATION DE LA MER
VOL. XIX. No. 3. 1954

Use of Otoliths for Determining the Age of Several Fishes from the Bering Sea.

By

Kenneth H. Mosher,
U.S. Fish and Wildlife Service.

SINCE there are few areas in the world today where the fishery stocks are not being exploited to some extent, the opportunity to study virgin populations is rare. Such an opportunity arose in June and July 1949 when the vessel "Deep Sea" was chartered by the U. S. Fish and Wildlife Service to investigate the fishery potentialities of the Bering Sea where previously there had been no regular trawl fishery[1]). Since information on the age-groups present in these virgin populations was of primary importance, it was first necessary to develop methods of determining the ages of the several species of bottom fish. The procedures described herein may be applicable in studies elsewhere of similar species.

The catch was predominantly of six species:—

Pacific cod (*Gadus macrocephalus* Tilesius)
Alaska pollack (*Theragra chalcogramma* Pallas)
  or whiting
Pacific halibut (*Hippoglossus stenolepis* Schmidt)
Lemon sole (*Pleuronectes quadrituberculatus* Pallas)
Rock sole (*Lepidopsetta bilineata* Ayres)
Starry flounder (*Platichthys stellatus* Pallas)

Otoliths were collected from all of these species as well as from a single specimen of yellowfin sole (*Limanda aspera* Pallas). For comparison a few scale samples were taken from the cod.

Techniques of Preparing the Otoliths for Age Study.

Otoliths taken in the field from fresh fish, or in the case of the lemon sole, from fish frozen aboard, were preserved dry in coin envelopes bearing identifying numbers. Upon gross examination in the laboratory the otoliths could be divided into two groups according to size and shape. Those of the Pacific cod and Alaska pollack were longer than wide, somewhat pointed at the ends, serrated along each edge, and crescent-shaped. The largest otoliths from this group measured 25 mm. by 11 mm. by 4 mm. and were taken from a cod 83 cm. in length. The other group consisted of flatfishes whose otoliths were somewhat disk-shaped with various irregularities. The largest earstones, 16 mm. by 2 mm. in size, were found in a halibut 124 cm. in length (se Figure 1).

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[1]) For details of this exploratory cruise, see Ellson, Powell, and Hildebrand, 1950.

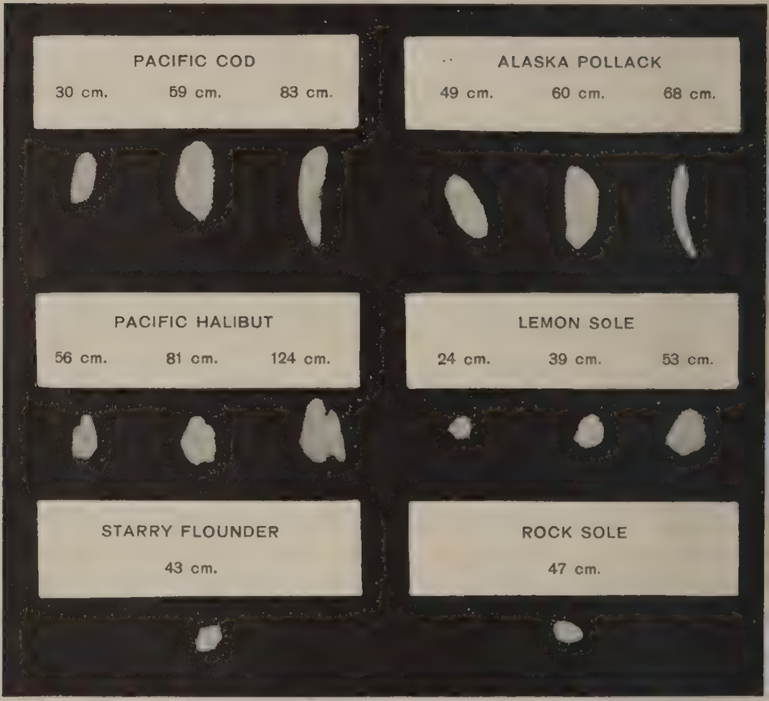
PACIFIC COD
30 cm.
59 cm.
83 cm.
ALASKA POLLACK
49 cm.
60 cm.
68 cm.
PACIFIC HALIBUT
56 cm.
81 cm.
124 cm.
LEMON SOLE
24 cm.
39 cm.
53 cm.
STARRY FLOUNDER
43 cm.
ROCK SOLE
47 cm.

Figure 1. Showing relative size and shape of otoliths from species collected. Largest cod and pollack otolith shown in side view.

Previous workers have obtained variable results in the use of otoliths for age determination in the bottom fishes. Numerous references found in the literature indicate the value of otoliths in the study of the Norwegian cod. Thompson (1914) determined the age of Pacific halibut from otoliths, and workers of the International Fisheries Commission have used otoliths in their halibut studies for many years. On the other hand, Harold G. Orcutt (1950) chose scales instead of otoliths in his research on the starry flounder in California waters and

F. C. Cleaver (1949) working with the starry flounder in Washington waters found the otoliths unsatisfactory for age determinations.

In the study of the Bering Sea collection a number of methods were tried in order to find the one which brought out most clearly the annular marks in each type of otolith. In every case interpretation of the otoliths was improved considerably by grinding the stones on a lapidary wheel using No. 600 abrasive. Because of the variation between species, the most successful procedures are considered separately.

Cod (*Gadus macrocephalus*) and pollack (*Theragra chalcogramma*). These otoliths remained opaque after soaking for weeks in Canada Balsam or glycerine, or even after boiling in these media. No mounting procedure, surface grinding or polishing gave any indication of internal markings whatever. A method in use by the Norwegian investigators in the study of their cod fishery and described orally by Mr. G. Rollefsen proved satisfactory with slight modification.

In this procedure the otolith was broken with the fingers transversely near the middle. To obtain the best definition of the marking, the broken surface was ground, washed, and dipped in glycerine. The piece of earstone was held upright on a microscope slide with wax or modelling clay, and the ground surface examined with a binocular microscope of suitable power. A beam of light from a microscope lamp was directed at right angles to the body of the otolith and when a finger or other object was held in exactly the right position to shade the ground face, the light travelled up through the internal layers to appear on the surface as a series of light and dark bands.

Lemon sole (*Pleuronectes quadrituberculatus*). Even after treatment in various media, no external evidence of annuli could be found on otoliths of this species except in the smallest specimens. However, after they had been ground nearly to the middle from opposite sides leaving a thin section of the earstone for study, the markings became evident. When the otoliths were examined over a black mat in reflected light, the annuli could be seen clearly.

Halibut (*Hippoglossus stenolepis*) and rock sole (*Lepidopsetta bilineata*). Although in some cases these earstones could be read if immersed in glycerine, the markings became much clearer when the concave surface was lightly ground.

Starry flounder (*Platichthys stellatus*) and yellowfin sole (*Limanda aspera*). The earstones of these species show only faint markings when dry or in glycerine, but by removing the opaque surface layer the annuli could be read without difficulty.

Age Determination Procedures.

Two readings of each pair of otoliths were made a day or more apart without reference to the fish length or the previous reading. If the two readings were not the same, a third reading was made at least a day later, and a decision reached as to the most probable age of the fish from which the earstones came. Excepting 33 of the cod specimens which were selected to represent the smaller sizes, all the fish in the collections were 5 years old or older. Since a reader has less chance of obtaining the same count twice in succession from older fish, the age compositions of virgin stocks containing older fish should give a lower percentage of agreement than those stocks which are regularly fished.

Although the percentage agreement of the first two readings bears some relation to the accuracy of the age determinations, and indicates the clarity of the markings, it is not possible to estimate the degree of accuracy from the limited collections available. Comparisons of ages for such species as are available indicate that the fish from the Bering Sea are slower growing and attain a greater age than similar fish from localities farther south. This is as expected.

Consistency of Results.

For the cod the first two readings were the same in 64·2 per cent. of the cases. All but seven of the age counts differed by only one year.

For the pollack the two readings agreed in 26 per cent. of the cases. The greater difficulty in interpreting these otoliths was attributed to (1) the slower growth-rate of these fish producing annuli closely crowded near the margin of the otolith, and (2) the greater confusion between true and false annuli found in this species. More collections from the Bering Sea with greater numbers of smaller fish are needed to substantiate the usefulness of these techniques in the age determination of the pollack.

For the lemon sole, 64·2 per cent. of the two readings were the same, indicating a fair degree of consistency in interpretation of the earstones. An interesting feature of the otoliths of this species was the central zone, containing the first 3 to 7 annuli, and resembling the freshwater portion of a sockeye salmon otolith. Beyond this zone, the annuli are less distinct and much farther apart as in the ocean growth portion of the sockeye earstone.

This growth pattern suggests that the young of the lemon sole grow very slowly for a few years. Possibly the nursery grounds are in brackish or inside waters, or in localities where they are crowded by the same or other species. After a varying period of time, they grow more rapidly perhaps by migration to areas of more abundant food or better growth conditions, or by the onset or result of sexual development.

For the other species, too few specimens were available to provide accurate information on the percentage agreement between the first two readings, although they indicated that the markings can be read with substantial consistency.

Mortality and Growth-Rates.

Because of the small size of most of the samples, no attempt has been made to determine the natural mortality rates of the different stocks of

Table 1. Age and Size Analysis of Pacific Cod from Bering Sea.

Length (cm.)	Age in Years (Number of Rings) 1	2	3	4	5	6	7	8	9	10	11	12	Sample Total
14·1—16·0	1	—	—	—	—	—	—	—	—	—	—	—	1
16·1—18·0	2	—	—	—	—	—	—	—	—	—	—	—	2
18·1—20·0	4	—	—	—	—	—	—	—	—	—	—	—	4
20·1—22·0	—	1	—	—	—	—	—	—	—	—	—	—	1
22·1—24·0	—	—	—	—	—	—	—	—	—	—	—	—	—
24·1—26·0	—	—	—	—	—	—	—	—	—	—	—	—	—
26·1—28·0	—	3	—	1	—	—	—	—	—	—	—	—	4
28·1—30·0	—	—	2	—	—	—	—	—	—	—	—	—	2
30·1—32·0	—	1	3	—	—	—	—	—	—	—	—	—	4
32·1—34·0	—	—	1	—	—	—	—	—	—	—	—	—	1
34·1—36·0	—	—	—	—	—	—	—	—	—	—	—	—	—
36·1—38·0	—	—	2	3	—	—	—	—	—	—	—	—	5
38·1—40·0	—	—	1	1	—	—	—	—	—	—	—	—	2
40·1—42·0	—	—	—	1	—	—	—	—	—	—	—	—	1
42·1—44·0	—	—	—	—	1	—	—	—	—	—	—	—	1
44·1—46·0	—	—	—	4	—	—	—	—	—	—	—	—	4
46·1—48·0	—	—	—	1	—	—	—	—	—	—	—	—	1
48·1—50·0	—	—	—	—	—	—	—	—	—	—	—	—	—
50·1—52·0	—	—	—	—	1	—	—	—	—	—	—	—	1
52·1—54·0	—	—	—	—	2	—	—	—	—	—	—	—	2
54·1—56·0	—	—	—	—	6	1	—	—	—	—	—	—	7
56·1—58·0	—	—	—	1	1	1	—	—	—	—	—	—	3
58·1—60·0	—	—	—	—	2	—	1	—	—	—	—	—	3
60·1—62·0	—	—	—	—	1	1	3	—	—	—	—	—	5
62·1—64·0	—	—	—	—	—	3	—	—	—	—	—	—	3
64·1—66·0	—	—	—	—	1	2	3	2	—	—	—	—	8
66·1—68·0	—	—	—	—	—	3	—	—	—	—	—	—	3
68·1—70·0	—	—	—	—	2	5	3	1	—	—	—	—	11
70·1—72·0	—	—	—	—	—	3	2	—	1	—	—	—	6
72·1—74·0	—	—	—	—	1	1	3	3	2	1	—	—	11
74·1—76·0	—	—	—	—	—	2	3	3	—	—	1	—	9
76·1—78·0	—	—	—	—	—	1	—	3	—	2	—	—	6
78·1—80·0	—	—	—	—	—	—	2	1	—	—	—	—	3
80·1—82·0	—	—	—	—	—	—	—	—	3	—	—	—	3
82·1—84·0	—	—	—	—	—	—	—	—	—	—	—	1	1
84·1—86·0	—	—	—	—	—	—	—	—	—	—	1	—	1
86·1—88·0	—	—	—	—	—	—	—	—	—	2	—	—	2
88·1—90·0	—	—	—	—	—	—	—	—	—	1	—	—	1
90·1—92·0	—	—	—	—	—	—	—	—	—	1	—	—	1
Sample Total	7	5	9	12	18	23	20	13	6	7	2	1	123

fish. However, for future comparison, the main features of the results are summarized below:—

Species	Range of ages	Age of maximum numbers
Pacific cod	1—12*)	6
Alaska pollack	6—15	11
Pacific halibut	5—14	7
Starry flounder	5—13	—
Rock sole	9—15	11, 12

*) Samples selectively supplemented by fish under 5 years of age.

Table 2. Age and Size Analysis of Pollack from Bering Sea.

Length (cm.)	Age in Years (Number of Rings) 6	7	8	9	10	11	12	13	14	15	16	Sample Total
46·1—48·0	—	—	2	—	—	—	—	—	—	—	—	2
48·1—50·0	—	1	1	1	—	—	—	—	—	—	—	3
50·1—52·0	1	1	—	—	—	—	—	—	—	—	—	2
52·1—54·0	—	—	—	1	—	—	—	1	—	—	—	2
54·1—56·0	—	—	—	—	—	—	1	—	—	—	—	1
56·1—58·0	—	—	1	—	2	—	—	—	—	—	—	3
58·1—60·0	—	—	—	—	—	2	—	—	—	—	—	2
60·1—62·0	—	—	—	—	—	1	1	—	1	—	—	3
62·1—64·0	—	—	—	1	—	1	—	—	—	—	—	2
64·1—66·0	—	—	—	1	—	1	1	—	—	—	—	3
66·1—68·0	—	—	—	—	—	—	—	1	—	1	—	2
68·1—70·0	—	—	—	—	—	1	—	—	—	—	—	1
70·1—72·0	—	—	—	—	—	—	—	—	—	—	—	—
72·1—74·0	—	—	—	—	—	—	—	1	—	—	—	1
Sample Total	1	2	4	4	2	6	3	3	1	1	0	27

Similarly, there were too few fish present to establish valid growth-rates. For reference in future work the detailed results of the age determinations for these fish are given in Tables 1—6. In addition,

Table 3. Age and Size Analysis of Lemon Sole from Bering

Length (cm.)	Age in Years (Number of Rings) 6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	Sa T
23·1—24·0	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	
24·1—25·0	—	1	1	1	—	—	—	—	—	—	—	—	—	—	—	—	
25·1—26·0	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	
26·1—27·0	—	—	2	—	1	—	—	—	—	—	—	—	—	—	—	—	
27·1—28·0	1	1	1	—	—	—	—	—	—	—	—	—	—	—	—	—	
28·1—29·0	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	
29·1—30·0	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	
30·1—31·0	—	—	—	2	—	—	—	—	—	—	—	—	—	—	—	—	
31·1—32·0	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—	
32·1—33·0	—	—	1	—	—	1	—	—	—	—	—	—	—	—	—	—	
33·1—34·0	—	—	—	—	1	1	1	—	—	—	—	—	—	—	—	—	
34·1—35·0	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	
35·1—36·0	—	—	—	—	—	1	—	—	1	—	—	—	—	—	—	—	
36·1—37·0	—	—	—	—	—	3	—	—	—	1	—	—	—	—	—	—	
37·1—38·0	—	—	—	—	—	1	—	1	1	—	—	—	—	—	—	—	
38·1—39·0	—	—	—	—	2	—	2	2	—	—	—	—	—	—	—	—	
39·1—40·0	—	—	—	—	1	—	—	1	2	1	—	—	—	—	—	—	
40·1—41·0	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—	
41·1—42·0	—	—	1	—	—	—	1	—	—	1	—	—	—	—	—	—	
42·1—43·0	—	—	—	—	—	—	1	—	—	1	—	—	—	—	—	—	
43·1—44·0	—	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—	
44·1—45·0	—	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—	
45·1—46·0	—	—	—	—	—	—	—	—	—	—	1	—	—	—	—	—	
46·1—50·0*)	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	
50·1—51·0	—	—	—	—	—	—	—	—	—	—	—	—	—	2	—	—	
51·1—52·0	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	
52·1—53·0	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	
53·1—54·0	—	—	—	—	—	—	—	—	—	—	1	—	—	—	—	1	
Sample Total	1	3	8	3	5	9	5	6	4	4	2	0	0	2	0	1	5

*) No records.

Table 4. Age and Size Analysis of Pacific Halibut from Bering Sea.

Length (cm.)	Age in Years (Number of Rings)										Sample Total
	5	6	7	8	9	10	11	12	13	14	
34·1— 36·0	1	—	—	—	—	—	—	—	—	—	1
36·1— 42·0*)	—	—	—	—	—	—	—	—	—	—	—
42·1— 44·0	1	2	—	—	—	—	—	—	—	—	3
44·1— 46·0	—	—	—	—	—	—	—	—	—	—	—
46·1— 48·0	1	—	—	—	—	—	—	—	—	—	1
48·1— 50·0	—	—	—	—	—	—	—	—	—	—	—
50·1— 52·0	—	—	1	—	—	—	—	—	—	—	1
52·1— 54·0	—	2	1	—	—	—	—	—	—	—	3
54·1— 56·0	—	—	1	—	—	—	—	—	—	—	1
56·1— 58·0	—	—	1	—	—	—	—	—	—	—	1
58·1— 60·0	—	—	—	2	—	1	—	—	—	—	3
60·1— 62·0	—	—	1	—	—	—	—	—	—	—	1
62·1— 64·0	—	—	—	—	—	—	—	—	—	—	—
64·1— 66·0	—	—	—	1	—	1	—	—	—	—	2
66·1— 74·0*)	—	—	—	—	—	—	—	—	—	—	—
74·1— 76·0	—	—	—	—	1	—	—	—	—	—	1
76·1— 78·0	—	—	—	—	—	—	1	1	—	—	2
78·1— 80·0	—	—	—	—	—	—	—	—	—	—	—
80·1— 82·0	—	—	—	—	1	1	1	—	—	—	3
82·1— 84·0	—	—	—	—	—	1	—	—	—	—	1
84·1— 86·0	—	—	—	—	—	—	1	—	—	—	1
86·1— 88·0	—	—	—	—	—	—	—	—	—	—	—
88·1— 90·0	—	—	—	—	—	—	—	1	—	—	1
90·1—124·0*)	—	—	—	—	—	—	—	—	—	—	—
124·1—126·0	—	—	—	—	—	—	—	—	—	1	1
Sample Total	3	4	5	3	2	4	3	2	0	1	27

*) No records.

Table 5. Age and Size Analysis of Starry Flounder from Bering Sea.

Length (cm.)	Age in Years (Number of Rings)										Sample Total
	5	6	7	8	9	10	11	12	13	14	
28·1—29·0	1	—	—	—	—	—	—	—	—	—	1
29·1—34·0*)	—	—	—	—	—	—	—	—	—	—	—
34·1—35·0	—	—	1	—	—	—	—	—	—	—	1
35·1—36·0	—	—	—	—	1	—	—	—	—	—	1
36·1—37·0	—	—	—	—	—	—	—	—	—	—	—
37·1—38·0	—	—	—	—	1	—	—	—	—	—	1
38·1—39·0	—	—	—	—	—	—	—	—	—	—	—
39·1—40·0	—	—	—	1	—	—	—	—	—	—	1
40·1—41·0	—	—	—	—	—	—	—	—	—	—	—
41·1—42·0	—	—	—	—	—	—	1	1	—	—	2
42·1—43·0	—	—	—	—	—	—	—	—	—	—	—
43·1—44·0	—	—	—	1	—	—	1	1	1	—	4
44·1—49·0*)	—	—	—	—	—	—	—	—	—	—	—
49·1—50·0	—	—	—	—	—	1	—	—	—	—	1
Sample Total	1	0	1	2	2	1	2	2	1	0	12

*) No records.

Table 6. Age and Size Analysis of Rock Sole from Bering Sea.

Length (cm.)	Age in Years (Number of Rings) 9	10	11	12	13	14	15	Sample Total
34·1—36·0	1	—	—	—	—	—	—	1
36·1—38·0	—	—	—	—	—	—	—	—
38·1—40·0	1	—	—	—	—	—	—	1
40·1—42·0	—	1	1	—	—	—	—	2
42·1—44·0	—	—	3	1	—	—	—	4
44·1—46·0	—	—	1	—	—	—	—	1
46·1—48·0	—	—	—	3	—	—	—	3
48·1—50·0	—	—	—	1	—	—	—	1
50·1—52·0	—	—	—	—	—	—	—	—
52·1—54·0	—	—	—	—	—	—	1	1
Sample Total	2	1	5	5	0	0	1	14

otoliths from one large specimen of yellowfin sole (*Limanda aspera*), a female 43·7 cm. in length, were examined; they indicated this fish to be 15 years old (in its 16th year).

Summary and Conclusions.

Age determinations from six species of fish collected in the Bering Sea in June and July 1949 were determined from the otoliths. The various procedures which were required to reveal the annuli for each species represented are described and the results presented in tabular form.

The results of this study indicate that all species examined can be aged satisfactorily if the otoliths are prepared properly. The limited collections made on this cruise point to the need for expanded study on all species to be found in this area.

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GRATORY PATTERN AND RACIAL STRUCTURE OF TLANTIC COAST STRIPED BASS

ARD C. RANEY,[1] WILLIAM S. WOOLCOTT AND ALBERT G. MEHRING
ell University, Ithaca, New York

his study gives the findings of an expanded investigation of racial
ks of Atlantic Coast striped bass, *Roccus saxatilis* (Walbaum),
was an outgrowth of work reported by Raney and de Sylva (1953:
). Details of the results of the Schaefer-*Salt Water Sportsman*
ging program are also presented. The region covered by the present
ly of racial stocks greatly extends that of the former work and was
le possible by the aid of the U. S. Fish and Wildlife Service, the
rt Fishing Institute, and the cooperation of many investigators
hom we give our thanks. Those who furnished material or other-
assisted greatly include H. M. Bearse, E. M. Burton, A. J.
houn, J. S. Coolidge, J. H. Cornell, R. W. Crawford, J. R. Greeley,
rim, E. C. Hayes, Jr., C. Heacox, A. S. Jones, I. M. Jones, E. A.
hner, H. Lyman, R. Mansueti, W. H. Massmann, J. L. McHugh,
. Robins, L. P. Schultz, R. P. Silliman, A. Schwartz, G. B. Talbot,
H. Underhill, G. F. Walton, J. R. Westman and C. L. Wheeler.

ll counts were made by the authors except for two series from the
Lawrence River, which were furnished by V. D. Vladykov. Counts

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[1] oordinator of "The Federal-State Striped Bass Research Program" for the U. S. Fish and
life Service. A. G. Mehring was the recipient of the Sport Fishing Institute Fellowship
952-53 and W. S. Woolcott held the same fellowship, 1953-54.

were made on young or yearlings, unless otherwise specified, in manner described by Raney and de Sylva (1953). Merriman (194 and Vladykov and Wallace (1952) have reported on previous attem to identify striped bass stocks. Studies on migration of striped ba include those by Pearson (1933), Merriman (1937 and 1941), Nevi (1940), Vladykov (1947), Vladykov and Wallace (1938 and 1952 and Raney (1954) who reported briefly on the migratory patte of the Hudson race. Other studies of migration are summarized Raney (1952). Recently Calhoun (1952) published an excellent stu on the migrations of California striped bass in the Sacramento-Sa Joaquin Delta area.

RACIAL STUDIES

The important sources of striped bass are known to be Albemar Sound, Chesapeake Bay, Delaware Bay and the Hudson River; oth populations are valuable for the local sport fishery. It is know that a stock produced at one locality may contribute greatly to fishery elsewhere along the coast. The study of races of striped ba by Raney and de Sylva (1953) concentrated largely on the Huds and Chesapeake stocks. Further material is now available and analyzed for those two waters and samples or data also have be obtained for the St. Lawrence River; Miramichi River, New Brun wick; Shubenacadie River, Nova Scotia; Albemarle Sound, Nor Carolina and several localities in South Carolina. Samples are st inadequate for many drainages. Further studies are needed an planned on different year classes from the same locality.

Studies of racial stock utilizing fin ray counts were made of youn of the 1953 year class from the Hudson River, several tributaries Chesapeake Bay, and Ablemarle Sound. Counts (Tables 1 to 4) soft rays of dorsal, anal, and pectoral fins and a character ind which consists of the sum of these counts, continues to give a hig percentage (70 per cent of separation between upstream Hudson an Chesapeake stocks. While this result is less than the 81 per cent sep ration found for previous year classes, especially that of 1949), it still a relatively high level of differentiation which probably justifi a continued designation as Hudson and Chesapeake races. The coun for 1953 samples were generally lower than those of previous yea The use of fin ray counts in separating stocks is most useful wh young bass of the same year class are compared.

Pectoral fin counts are apparently not as useful as was indicat earlier in the studies and several stocks of the 1953 year class show unexpectedly low counts with rather large variation. Pectoral fi also have been noted to be abnormal in several samples of adults an ionally were partially destroyed so that an accurate count was ult or impossible to obtain.

r the samples available before 1953, pectoral rays, of all the single acters, gave the most consistent and highest percentage of separa- It is still true that Hudson race samples are separable from apeake race samples using pectoral counts from the same year but low counts from young of the 1953 year class from the Rappa- ock and the Patuxent rivers indicates that perhaps this character be modified to a considerable degree by changing physical con- ns. It may also be that subraces, low in pectoral ray counts, in the upstream reaches of these rivers.

orsal ray counts, which in earlier studies seemed to vary in a more tic manner, gave the most consistent separation for the two main s under consideration; mode for Hudson 11, for Chesapeake 12. examaination of samples of ten or more specimens from a locality cates that this difference holds consistently. An examination of al counts in Table 1 shows that the Hudson race (Haverstraw and ream stations) have low counts; more often 11 than 12 while reverse is true for the stock present downstream from Haverstraw, York and elsewhere. The most southern samples from South and th Carolina and a far north sample from Nova Scotia are highest lorsal counts. It is of interest also that the extreme geographical ples (Carolina *vs.* Nova Scotia) are very high or highest in anal counts. An index combining these two counts separates a high entage of these populations from most others.

general anal rays are less likely to show geographic trends which now be interpreted as significant. However they seem to be of e in delimiting certain subraces as illustrated by the counts for a Scotia in Table 2.

urther evidence of the presence of different stocks within a inage system, such as Chesapeake Bay, was found, but a relatively level of differentiation was indicated. Those from the James River em continue to show low counts in contrast with the high counts d in adjacent York River. An indication of an upstream and a nstream population in some rivers such as the Rappahannock is d. Several year classes from the Hudson River suggest that the dson race is an upstream form which apparently is limited to the nity of Haverstraw and northward, while a quite different stock, fin ray counts similar to the James River population of the Chesa- ke race, exists in the lower part of the river south of Haverstraw. e detailed studies are necessary to determine the precise status of e subraces.

TABLE 1. NUMBER OF DORSAL SOFT RAYS IN YOUNG AND YEARLING STRIPED BASS. THE COLUMN (%) GIVES THE PERCENTAGE OF SPECIMENS WITH 11 OR FEWER DORSAL SOFT RAYS

Locality and year class	No. of	Dorsal rays								
	Series	9	10	11	12	13	14	No.	Mean	%
St. Lawrence R., Neuville, 1944-46	2	....	1	30	69	....	....	100	11.7	31
Miramichi R., N.B., 1952	1	....	10	17	124	1	....	144	11.9	13
Shubenacadie R., N.S., 1922	2	....	....	1	38	....	....	39	12.0	3
Mianus R., Cos Cob, Conn., 1948	1	....	3	23	18	....	....	44	11.3	59
Hudson R., N. Y.										
Coxsackie, 1953	1	....	2	47	15	....	....	64	11.2	77
Athens, 1949	1	1	5	14	3	....	....	23	10.9	87
West Camp to Marlboro, 1949, 52, 53	23	....	5	52	2	1	....	71	11.1	81
Haverstraw and Stony Pt., 1949	5	1	12	70	18	....	1	102	11.1	81
Haverstraw, 1952	3	....	....	10	2	....	....	12	11.2	83
Haverstraw, Sept. 1953	1	....	....	34	35	1	....	70	11.5	49
Haverstraw, 1936	1	....	....	10	20	....	....	30	11.7	33
South Haverstraw, 1953	6	1	....	12	17	....	....	30	11.5	43
Delaware Bay, 1951, 52, 53	3	....	3	50	66	4	....	123	11.5	43
Delaware Bay, 1951	1	....	1	20	42	3	....	66	11.7	32
Delaware Bay, 1952	2	....	2	29	20	....	....	51	11.3	61
Chesapeake Bay System										
Bay N. of Potomac R., 1882-1953	34	....	1	29	155	1	....	186	11.3	16
Patuxent R., 1921-1953	9	....	1	18	70	....	....	89	11.8	21
Potomac R., 1879-1953	28	....	1	49	96	1	....	147	11.6	34
Rappahannock R., 1921-1953	7	....	2	62	151	....	....	215	11.6	30
York R., 1921-1953	31	....	....	61	183	3	....	247	12.2	25
James R., 1878-1953	14	....	2	29	32	3	1	67	11.5	46
Albemarle Sound, N. C., 1880-1953	4	....	....	9	51	....	....	60	11.8	15
Edisto, Ashley & Santee R., S. C. 1938-53	5			1	9	....	....	10	11.9	10

TABLE 2. NUMBER OF ANAL RAYS IN YOUNG AND YEARLING STRIPED BASS. THE LAST COLUMN (%) GIVES THE PERCENTAGE OF SPECIMENS WITH 10 OR FEWER ANAL RAYS. THE NUMBER OF COLLECTIONS FROM EACH LOCALITY IS THE SAME AS GIVEN IN TABLE 1.

Locality and year class	Anal rays										
	7	8	9	10	11	12	13	14	No.	Mean	%
St. Lawrence R., Neuville, 1944-46	....	....	....	21	79	....	....	....	100	10.8	21
Miramichi R., N.B., 1952	1	1	13	61	66	1	1	....	144	10.4	53
Shubenacadie R., N.S., 1922	....	....	....	....	39	....	....	....	39	11.0	0
Mianus R., Cos Cob, Conn., 1948	....	....	....	13	31	....	....	....	44	10.7	30
Hudson R., N. Y.											
Coxsackie, 1953	....	....	1	27	36	....	....	....	64	10.6	44
Athens, 1949	....	....	1	5	14	3	....	....	23	10.9	87
West Camp to Marlboro, 1949, 52, 53	....	....	1	29	41	....	....	....	71	10.6	42
Haverstraw and Stony Pt., 1949	....	....	5	46	51	....	....	....	102	10.4	51
Haverstraw, 1952	....	....	....	3	9	....	....	....	12	10.8	25
Haverstraw, 1953	....	....	....	15	55	....	....	....	70	10.8	21
Haverstraw, 1936	....	....	....	5	25	....	....	....	30	10.8	20
South Haverstraw, 1953	....	....	....	6	24	....	....	....	30	10.2	20
Delaware Bay, 1951, 52, 53	....	....	1	24	97	1	....	....	123	10.4	20
Delaware Bay, 1951	....	....	1	5	59	1	....	....	66	10.9	9
Delaware Bay, 1952	....	....	....	17	34	....	....	....	51	10.7	33
Chesapeake Bay System											
Bay N. of Potomac R., 1882-1953	....	....	....	16	170	....	....	....	186	10.9	9
Patuxent R., 1921-53	....	....	....	10	79	....	....	....	89	10.9	11
Potomac R., 1879-1953	....	....	....	21	125	1	....	....	147	10.9	15
Rappahannock R., 1921-1953	....	....	....	37	177	1	....	....	215	10.8	17
York R., 1921-53	....	....	....	28	219	1	....	....	248	10.9	11
James R., 1878-1953	....	....	....	12	55	....	....	....	67	10.8	18
Albemarle Sound, N. C. 1880-1953	....	....	....	4	56	....	....	....	60	10.8	10
Edisto, Ashley & Santee R., S. C., 1938-53	....	....	....	1	9	....	....	....	10	10.9	10

TABLE 3. NUMBER OF PECTORAL RAYS (BOTH SIDES) IN YOUNG AND YEARLING STRIPED BASS. THE LAST COLUMN (%) GIVES THE PERCENTAGE OF SPECIMENS WITH 32 OR FEWER PECTORAL RAYS. THE NUMBER OF COLLECTIONS FROM EACH LOCALITY IS THE SAME AS GIVEN IN TABLE 1.

Locality and year class	Pectoral rays														
	27	28	29	30	31	32	33	34	35	36	37	38	No.	Mean	%
Miramichi R., N. B., 1952	....	....	....	....	....	13	14	112	5	....	....	....	144	33.8	9
Shubenacadie R., N. S., 1922	....	....	....	....	....	3	7	25	4	....	....	....	39	33.8	8
Mianus R., Cos Cob, Conn., 1948	....	....	....	1	....	21	12	10	....	....	....	....	44	32.7	50
Hudson R., N. Y.															
Coxsackie, 1953	....	1	3	2	6	47	3	....	1	....	....	....	63	31.7	94
Athens, 1949	....	1	1	3	6	7	2	1	....	....	....	....	21	31.3	86
West Camp to Marlboro, 1949, '52, '53	....	....	3	4	7	30	9	18	....	....	....	....	71	32.3	62
Haverstraw & Stony Pt., 1949	....	....	....	5	10	50	19	17	....	....	....	....	101	32.3	64
Haverstraw, 1952	....	....	....	....	2	4	5	1	....	....	....	....	12	32.4	50
Haverstraw, 1953	....	....	....	3	5	39	11	10	1	1	....	....	70	32.4	67
Haverstraw, 1936	....	....	....	1	3	15	7	4	....	....	....	....	30	32.3	63
South Haverstraw, 1953	....	....	....	....	....	6	9	13	....	1	....	....	29	33.4	21
Delaware Bay, 1951, '52, '53	....	....	2	....	9	29	27	37	15	1	....	....	120	33.1	33
Delaware Bay, 1951	....	....	2	....	7	12	12	18	14	....	....	....	65	33.1	32
Delaware Bay, 1952	....	....	....	....	2	14	14	18	....	1	....	....	49	33.0	35
Chesapeake Bay System															
Bay N. of Potomac R., 1882-1953	....	....	....	5	3	49	25	79	16	7	1	....	185	33.3	31
Patuxent R., 1921-53	....	....	....	5	2	32	16	27	4	1	1	....	88	32.8	44
Potomac R., 1879-1953	....	1	2	2	3	12	31	79	13	2	....	....	145	33.5	14
Rappahannock R., 1921-1953	1	3	4	10	11	61	49	62	5	2	1	1	210	32.7	42
York R., 1921-53	....	....	....	1	5	18	36	124	31	24	2	....	241	33.9	10
James R., 1878-1953	....	....	....	....	3	10	11	35	6	1	1	....	67	33.5	19
Albemarle Sound, N.C., 1880-1953	....	....	....	....	....	26	10	24	....	....	....	....	60	32.9	43
Edisto, Ashley, & Santee R., S. C., 1938-53	....	....	....	....	1	5	1	3	....	....	....	....	10	32.6	60

TABLE 4. FREQUENCY DISTRIBUTIONS OF THE CHARACTER INDEX (SUM OF SOFT RAYS OF DORSAL, ANAL AND BOTH PECTORAL FINS) IN YOUNG AND YEARLING STRIPED BASS. THE LAST COLUMN (%) GIVES THE PERCENTAGE OF SPECIMENS WITH AN INDEX OF 55 OR LESS. THE NUMBER OF COLLECTIONS FROM EACH LOCALITY IS THE SAME AS GIVEN IN TABLE 1.

Locality and year class	Character index													No.	Mean	%
	49	50	51	52	53	54	55	56	57	58	59	60	61			
Miramichi R., N. B., 1952	....	....	....	2	4	11	22	50	48	7	....	....	....	144	56.0	27
Shubenacadie R., N. S., 1922	....	....	....	....	....	....	3	8	24	4	....	....	....	39	56.7	8
Mianus R., Cos Cob, Conn., 1948	....	1	....	1	5	10	15	8	4	....	....	....	....	44	54.7	73
Hudson R., N. Y.																
Coxsackie, 1953	....	2	1	3	24	21	10	....	....	1	....	....	....	62	53.6	98
Athens, 1949	1	3	3	2	5	3	4	....	....	....	....	....	....	21	52.5	100
West Camp to Marlboro, 1949, '52, '53	....	3	2	7	11	26	10	6	6	....	....	....	....	71	54.0	83
Haverstraw & Stony Pt., 1949	....	....	7	12	21	28	20	9	4	....	....	....	....	101	53.8	87
Haverstraw, 1952	....	....	....	1	1	4	5	1	....	....	....	....	....	12	54.3	92
Haverstraw, 1953	....	....	....	3	13	15	20	10	8	....	1	....	....	70	54.7	73
Haverstraw, 1936	....	....	....	2	2	5	14	4	3	....	....	....	....	30	54.8	77
South Haverstraw, 1953	....	....	1	1	1	5	5	6	11	....	....	....	....	30	55.5	43
Delaware Bay, 1951, '52, '53	....	....	1	1	11	20	26	25	25	10	1	....	....	111	55.7	45
Delaware Bay, 1951	....	....	1	....	4	12	9	12	17	9	1	....	....	65	55.8	40
Delaware Bay, 1952	....	....	....	1	7	7	16	10	7	1	....	....	....	49	55.0	63
Chesapeake Bay System																
Bay N. of Potomac R., 1882-1953	....	....	....	....	8	11	51	27	67	16	5	....	....	185	56.1	38
Patuxent R., 1921-53	....	....	....	....	7	10	31	15	21	3	1	....	....	88	55.5	55
Potomac R., 1879-53	....	1	3	1	3	10	23	37	55	11	1	....	....	145	56.0	28
Rappahannock R., 1921-53	....	2	2	9	15	26	50	50	45	4	2	1	1	207	55.3	50
York R., 1921-53	....	....	....	1	3	6	34	56	88	29	22	1	....	240	56.7	18
James R., 1878-1953	....	....	....	2	1	4	15	21	18	4	2	....	....	67	56.0	33
Albemarle Sound, N. C., 1880-1953	....	....	....	....	1	5	21	14	19	....	....	....	....	60	55.7	45
Edisto, Ashley & Santee R., S. C., 1938-53	....	....	....	....	....	1	6	1	2	....	....	....	....	10	55.4	70

The Delaware stock seems somewhat intermediate but falls close
the Chesapeake race on the character index. There is considerable d
ference in some counts between the two year classes (1951 and 19
which are adequately represented. Almost all Delaware specim
were taken at the end of their second summer and perhaps repres
slightly different stocks, one of which is perhaps an upstream fo
Study of additional samples over several years may clarify t
problem.

The Albemarle Sound population is similar to the Chesapeake r
in fin ray counts but the rather compact distribution gives further
dication that these bass are an endemic group. Previous scanty retu
from tagging reported by Merriman (1941) imply the same conclusi

The small sample from the Edisto and Santee rivers, South Caroli
is similar to the geographically adjacent population of Albema
Sound, North Carolina, in dorsal and anal counts. However, the So
Carolina population has a low pectoral count and a low lateral l
scale count (Table 5) which permits almost a 100 per cent separat
and indicates a considerable degree of endemism for this stock.

TAGGING PROGRAM

The returns from the Schaefer-*Salt Water Sportsman* tagging p
gram were made available by Henry Lyman. This project was beg
in 1948 with the cooperation of the membership of various bass fishi
clubs. The object was to encourage fishermen to tag as many bass
possible, and 9,320 were tagged through 1952 at which time the proj
was terminated. Yearly prizes were offered to clubs and to individu
tagging the greatest number, but no rewards were given for returr
tags. Tagging was done in the region from Massachusetts to Che
peake Bay, but most was in the western quarter of Long Island Sou
where about two-thirds were tagged. In the vicinity of Greenwi
Connecticut, Edwin W. Morrell was especially active and during
year (1951) affixed more than 1,000 tags.

The tags used were Peterson discs of red and white vinylite
inch in diamater, 0.020 in thickness, with a center hole .040 ir
in diameter. On the white tag was printed "Schaefer Tag No." f
lowed by a serial number; on the red "*Salt Water Sportsman* Retu
Both Discs Boston, Mass." The pins were number 20 gauge, .
inch in diameter and 1.625 inches long. The first used were of p
nickel although later pins were a nickel alloy. The tags were affix
by piercing the posterior caudal peduncle just anterior to the caud
fin base (presumably through or near the hypural plate). The f
length in 95 per cent of those tagged was 16 inches or less and

TABLE 5. FREQUENCY DISTRIBUTION OF LATERAL LINE SCALE COUNTS IN STRIPED BASS FROM ALBEMARLE SOUND, NORTH CAROLINA, AND THE EDISTO AND SANTEE RIVERS, SOUTH CAROLINA. THE LAST COLUMN (%) INDICATES THE PERCENTAGE OF SPECIMENS WITH 60 OR FEWER LATERAL LINE SCALES.

Locality	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	No.	Mean	%
Albemarle Sound, N. C.	....	....	....	....	....	....	....	....	1	9	7	2	1	4	2	26	62.5	3.9
Edisto and Santee R., S. C.	2	1	....	2	1	....	2	....	2	....	....	....	....	....	....	10	56.1	100

TABLE 6. FORK LENGTH OF STRIPED BASS WHEN ORIGINALLY TAGGED FROM 1948-52 IN THE AREA FROM MASSACHUSETTS TO CHESAPEAKE BAY

Length in inches	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Number	2	6	27	95	88	73	77	86	91	80	51	14	9	2	2	1	3	2	1

usually 9 to 15 inches. The frequency distribution of the length o those tagged is shown in Table 6; two additional specimens not listed were 29 inches long and one was 32 pounds.

Some 792 (8.5 per cent of those tagged) were returned, of which 764 had usable data. Of these 92 per cent were recovered within a year Tags were usually returned within 5 to 9 months and only a few were out more than 20 months (see Table 7). The best rate of return came early in the program (1950-51) when there may have been less bitterness between groups utilizing the resource.

While this type of tagging program has produced results of value it is recommended that it not be tried again. Since the general migratory habits of striped bass along the Atlantic Coast are fairly well known, future tagging programs should be designed with a definite purpose in mind. They should be carried on by fishing research agencies, rewards (probably at least $1) should be offered for returns, and an intensive follow-up should be made in each area to insure the maximum possible recovery. The purpose of the program should be explained to those engaged in the fishery where captures are expected. The nature of the fishery and opportunity for recovery of tags in the regions concerned should be carefully considered in interpreting results. The studies of Calhoun, Fry and Hughes (1951) and Calhoun (1953) indicate great need for further experimentation with materials used for tags and pins.

Western Long Island Sound. The tagging results are significant mostly in relation to the stock fished in the western quarter of Long Island Sound during spring, summer, and fall. Fin ray counts of specimens of the 1949 year class obtained from Cos Cob, Connecticut, indicate this stock to be largely of the Hudson race. Several thousand bass were tagged in this area and 555 were recovered; of these 372 (67 per cent) were retaken in the Hudson River, mostly in the spring fishery; 156 (28 per cent) were recaptured in the western quarter of Long Island Sound (seldom east of Fairfield, Connecticut, or Northport, Long Island) and only 27 (5 per cent) were recaptured from elsewhere (see Table 8 and Figure 1). Of the latter, five were retaken off Connecticut and Rhode Island from the mouth of the Connecticut River and eastward; eight were caught on the eastern and southeastern end of Long Island; six were taken in New Jersey at Great Bay (2), Toms River (1), Maurice River (1), Barnegat Bay (1) and Mullica River (1); and four were taken in both Delaware Bay and Chesapeake Bay.

More tags were recovered of those attached in 1950 than for any other single year. Of those tagged at Greenwich, Connecticut, and

TABLE 7. DISTRIBUTION OF TIME LAPSE BETWEEN TAGGING AND RECOVERY OF
IN THE AREA MASSACHUSETTS TO CHESAPEAKE BAY

No. of months	1—	1	2	3	4	5	6	7	8	9	10	11	12	13	14
No. of recoveries	27	29	36	36	33	63	77	75	85	45	33	24	13	8	8
No. of months	15	16	17	18	19	21	22	23	24	26					
No. of recoveries	5	6	1	1	1	2	1	1	3	1					

TABLE 8. SUMMARY OF 555 RECAPTURED STRIPED BASS ORIGINALLY TAGGED IN THE WESTERN QUARTER OF LONG ISLAND SOUND

Locality and year tagged	Number recaptured			
	Total	Hudson River	W. quarter L.I. Sound	Other localities
W. end Long Island Sound N. Shore, New York, 1950-52	14	10	2	2 Saybrook, Conn., & Montauk, L. I.
Greenwich, Conn., 1950	234	180	43	11 Sag Harbor & Gardiners Bay, L. I., Providence, R. I., Toms R. & Great Bay, N. J., Delaware Bay (3); Chesapeake Bay (3)
Greenwich, Conn., 1951	146	99	45	2 Thames R., Conn., & Great Bay, N. J.
Greenwich, Conn., 1952	45	18	26	1 Montauk, L. I.
Stamford to Fairfield, Conn., 1948-52				5 Conn. R., Conn.; Bridgehampton, L. I.; Maurice R., N. J.
South Shore—Whiteside to Northport, L. I., 1948-52	76 40	53 12	18 22	6 Delaware Bay; James R., Va. Niantic R., Conn.; East Hampton & Moriches Bay, L. I.; Barnegat Bay & Mullica R., N. J.; Chincoteague Inlet, Va.
Totals (percentage)	555	372 (67%)	156 (28.1%)	27 (4.9%)

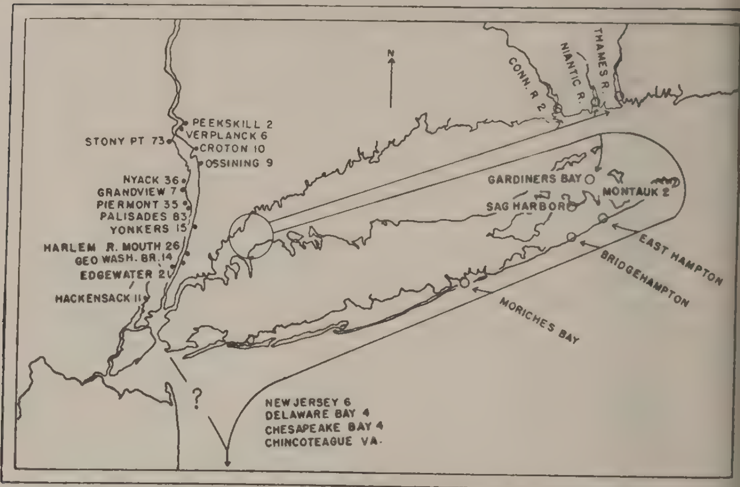
N
CONN. R 2
NIANTIC R.
THAMES R.
PEEKSKILL 2
VERPLANCK 6
STONY PT 73
CROTON 10
OSSINING 9
NYACK 36
GRANDVIEW 7
PIERMONT 35
PALISADES 83
YONKERS 15
HARLEM R. MOUTH 26
GEO WASH. BR. 14
EDGEWATER 2
HACKENSACK 11
GARDINERS BAY
SAG HARBOR
MONTAUK 2
EAST HAMPTON
BRIDGEHAMPTON
MORICHES BAY
?
NEW JERSEY 6
DELAWARE BAY 4
CHESAPEAKE BAY 4
CHINCOTEAGUE VA.

Figure 1. Map of Long Island, New York and the Hudson River showing the localities a which 555 tagged striped bass were recovered. They were originally tagged in the wester end of Long Island Sound (marked by large circle on map), mostly in the vicinity of Green wich, Connecticut (see Table 8). Those recaptured from the Hudson River for which spe cific locality data were not available are not indicated. The number of recaptures at a indicated locality is one unless otherwise noted after the place name.

nearby localities such as Cos Cob, 234 were recovered. For those for which precise date of tagging is available the data are as follows: May (8), June (14), July (53), August (59), September (58) and October (16). Of the 234 recovered 76.3 per cent were taken in the Hudson River drainage. Most of these (164 bass) were captured in the Hudson River during the spring fishery in April and May. Eight per cent were recaptured at Greenwich or Cos Cob within several miles of the place where they were tagged, the same summer or fall (8 speimens), the following summer and winter (9 specimens) or the summer of 1952 (2 specimens). By-month recoveries were May (4), June (2), July (6), August (1), September (3), October (2) and January (1). An additional 7.2 per cent were captured in the western quarter of Long Island Sound in nearby areas. These were captured in April (1), June (1), July (4), August (7), September (3), and October (1), and except for one recaptured in 1952 were about evenly divided between 1950 and 1951. This seems to connote a summer population which does not move far from the western quarter of Long Island Sound. These presumably are joined from time to time and in varying, but usually small numbers, of Chesapeake stock which find their way westward in the Sound rather than following the usual migratory path rthward to Massachusetts. This assumption is based on the results tagging in 1950 which show that only 3 per cent migrated as far as elaware and Chesapeake Bays and only 1.6 per cent were recovered far away as eastern Long Island and New Jersey.

The 146 returns from those tagged at Greenwich and Cos Cob, Conecticut, in 1951 gave a similar picture but with fewer returns from e south; the Hudson River produced 68 per cent, mostly during the ring following tagging. From the locality of tagging (Greenwich) 3 per cent were recaptured and 12 per cent retaken in nearby areas the western quarter of Long Island Sound. Only 2 per cent were ken as far as western Connecticut and New Jersey.

Six bass 9 to 10 inches long tagged at Greenwich, Connecticut, on ugust 25 and September 6-10, 1952, were recaptured nearby below he Cos Cob, Connecticut, power dam on January 20, 1953. Fishermen ith a thorough knowledge of local conditions report that for the past 0 years bass have been taken from time to time in the winter at the ower plant "flume."

Bass tagged at other localities in the western quarter of Long Island ound also show the same general pattern of movement, the vast maority being captured in the Hudson River or at areas close to the oint where tagged.

Hudson River and New York bays. At The Narrows which separate ower from Upper New York Bay numerous bass were tagged, mostly rom September 9 to November 18 in 1950 and 1951; 92 were recovered. During the following two spring seasons and in the fall of 1952, 39 (96.7 per cent of those recovered) were recaptured in the Hudson River and its tributary, the Hackensack River. As may be noted in Table 9, most recoveries were made in the spring; 43 in 1951 and 31 in 1952 compared with fall recaptures of 12 in 1951 and none in 1952. All recoveries were made during the first spring or in the fall one year after they were tagged which apparently is due to a lack of permanency of the tags rather than an indication of the natural mortality of the stock. Virtually all tags were returned from the fishermen engaged in the spring shad fishing, without whose fine cooperation little data would have accumulated. However, it is known that many tags were recovered and not made available. The sparsity of returns from sport anglers seems to indicate a paucity of the latter rather than any shortage of striped bass.

One striped bass tagged in April, 1952, was recovered later that spring in the Hudson River at Edgewater, New Jersey. Two others tagged at the Narrows on July 5 and 6, 1952, were recaptured between Palisades and Hastings-on-Hudson in the spring of 1953. Three speci-

TABLE 9. LOCALITIES IN THE HUDSON RIVER DRAINAGE OF RECAPTURES OF 86 STRIPED BASS ORIGINALLY TAGGED DURING THE PERIOD FROM SEPTEMBER 9 TO NOVEMBER 18, 1950 AND 1951 AT THE NARROWS, BETWEEN UPPER AND LOWER NEW YORK BAYS, NEW YORK CITY. RECAPTURES IN 1951 WERE ORIGINALLY TAGGED IN THE FALL OF 1950 EXCEPT THOSE INDICATED IN ITALICS IN THE SECOND COLUMN BELOW, WHICH WERE TAGGED IN THE FALL OF 1951. ALL THOSE RECAPTURED IN THE SPRING OF 1952 WERE ORIGINALLY TAGGED IN THE FALL OF 1951.

	Year Recovered			
	1951		1952	
	Spring	Fall	Spring	
Locality of recapture	April-May	Sept.-Dec.	Mar.-June	Total
Hudson River				
Locality not specified	1	....	....	1
Stony Point	19	1 + *7*	....	27
Ossining	1	....	....	1
Nyack	1	1 + *3*	....	5
Grandview	1	....	....	1
Piermont	1	....	11	12
Palisades	4	....	10	14
Yonkers	1	....	2	3
Harlem River mouth	5	....	....	5
George Washington bridge	1	....	....	1
Edgewater, N. J.	8	....	5	13
Hackensack River	....	....	3	3
Totals	43	2 + *10*	31	86

mens (3.3 per cent of those recovered were taken elsewhere and were recaptured in New Jersey within 50 miles of The Narrows where they were tagged. One tagged October 29, 1950, was recaptured in the river at Highlands, New Jersey, near the Highland River bridge on April 3, 1951; another marked November 10, 1951, was taken on February 6, 1952, in Shark River, New Jersey; the third was tagged November 18, 1950, and was taken in the Toms River area during the week of February 10, 1952.

The same type of upstream movement of striped bass was noted from 34 recaptures in the Hudson River originally tagged in 1948 (6 specimens), 1950 (12 specimens), and 1951 (16 specimens) in Upper New York Bay. Five of these were first tagged during the period July 3 to August 22 and the remainder were marked from September 17 to November 17. All 34 recaptures were from the Hudson and 29 were made in the spring during the period March to June; five were taken in the period September to December. With five recoveries no more precise data on locality of recapture are available than Hudson River. The other 29 recoveries were as follows: Peekskill (1), Stony Point (5), Ossining (1), Nyack (7), Piermont (6), between Palisades and Hastings-on-Hudson (5), mouth of Harlem River (1), and Edgewater (3). Five recoveries were made during the same fall in which they were originally tagged which gives further evidence of a movement upstream into the Hudson River, perhaps for overwintering purposes.

Another series of striped bass was originally tagged at Gravesend ay and Hoffman Island (Lower New York Bay). Five were recap- red in the Hudson River during October and November, 1951. One arked at Hoffman Island on October 14 was retaken at Stony Point November 11, 1951. Single specimens were recovered in May to ıne from Hyde Park, Verplanck, Alpine, and Hackensack River.

A summary of 133 recoveries of striped bass originally tagged in ower New York Bay, the Narrows and Upper New York Bay shown Figure 2 reveals that all but three (2.3 per cent) were retaken in ıe Hudson River upstream from the point of tagging. Only two (re- ıptured at Toms River and Shark River, New Jersey) actually moved ny considerable distance outside the area since the third was recap- ıred at Highland, New Jersey, which is located at the southernmost oint of Lower New York Bay.

It is inferred from the above data that there is a large movement up he Hudson River either in the fall of the year or early in the spring. Vhen viewed in the light of our knowledge of the existence of an up- tream Hudson River race, this movement seems to be, at least in part, spawning migration. It also appears that the Hudson River race nd a relatively small proportion of the Chesapeake race also winter n the Hudson River. The possibility seems remote that any con- iderable number which pass downstream through the Narrows go any onsiderable distance either north or south.

Twelve were recaptured in the Hudson River which originally were agged in the Hudson in the stretch from 96th Street, New York City, o the Albany-Troy dam. None tagged in the Hudson were recaptured utside the Hudson. The only known upstream migrant was tagged ıt Englewood, New Jersey, on May 4, 1952, and was recaptured at Piermont, New York, in late May. Three moved downstream; one agged at the Albany-Troy dam June 2, 1951, was retaken at Stony Point October 29, 1951; a second tagged at Stony Point on September 16, 1951, was recaptured at Upper Nyack, New York, in late October 1951; and a third marked off Haverstraw in September 1951 was taken in October at Upper Nyack. Six striped bass originally tagged off Stony Point in 1951 were recaptured at or close to the area of release. For these, the dates of tagging followed by the date of recovery (in parentheses) are July 26 (August 20), September 16 (October 29), September 30 (October 29), October 3 (October 7), September 19 (September 30, and September 19 (November 11). There is an indication here of a wintering population near Stony Point. This was a well known fact to commercial fishermen who formerly fished the area near Stony Point and Haverstraw in the fall.

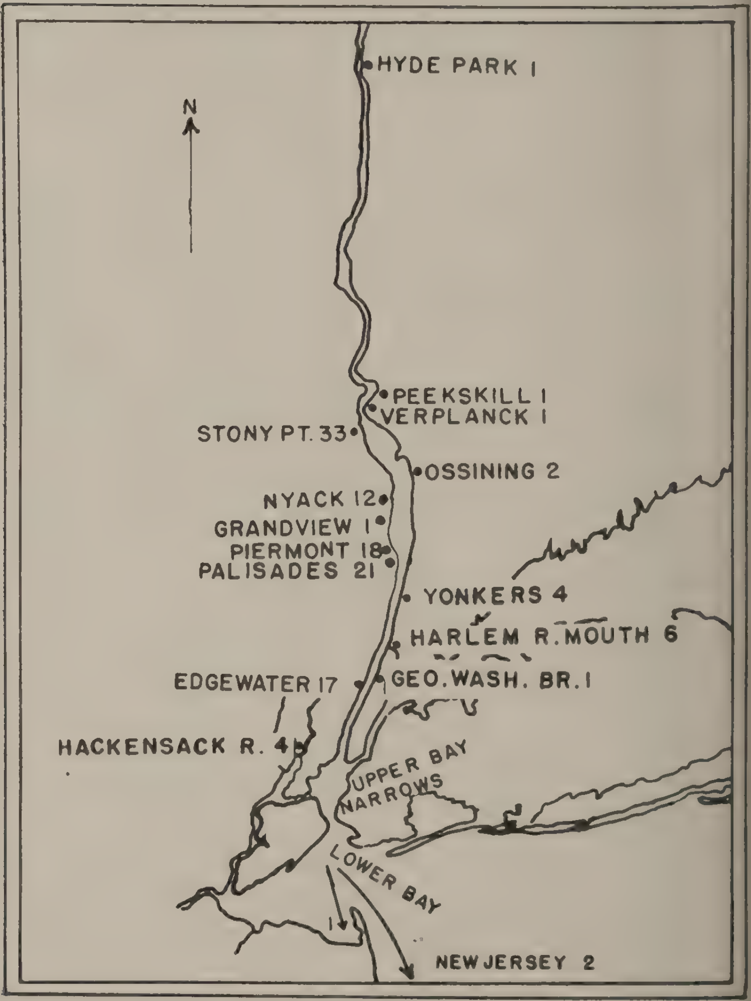
N
HYDE PARK 1
PEEKSKILL 1
VERPLANCK 1
STONY PT. 33
OSSINING 2
NYACK 12
GRANDVIEW 1
PIERMONT 18
PALISADES 21
YONKERS 4
HARLEM R. MOUTH 6
EDGEWATER 17
GEO. WASH. BR. 1
HACKENSACK R. 4
UPPER BAY
NARROWS
LOWER BAY
1
NEW JERSEY 2

Figure 2. Map of the Hudson River, New York showing the locality of recovery of striped bass tagged in the Upper New York Bay (34 specimens), The Narrows (92) and the Lower New York Bay (5). Most were tagged during September to November 1950 and 1951 and the majority were recaptured the following spring.

Southwestern Long Island. Data on the recaptures of 32 striped ass originally tagged in 1949, '50 and '51 along the southwest shore f Long Island from Coney Island to Jones Beach are available. Tags were originally affixed from April 3 to November 20; two-thirds were agged in the fall after September 1. Six (18.8 per cent) were taken n April, June and November, in the same area where they were agged. Sixteen (50 per cent) were taken in the Hudson River from Verplanck to Yonkers. Of these, 3 were taken in August and September and the remainder in the spring from March to May. A single specimen tagged at Jones Beach, April 18, 1951, had moved to Port Jefferson on the north shore of Long Island by July 9, 1951. Another, tagged on July 21, 1951, in Swift Creek, Freeport, was one of an overwintering group taken at the Cos Cob, Connecticut, power dam on January 20, 1953. One tagged at Far Rockaway May 6, 1951, was recaptured on July 20, 1951, in Great South Bay, Long Island.

Only 6 specimens or 19.3 per cent of all recaptures were recovered any considerable distance from the release area. One tagged at Jones Beach, April 28, 1951, was found at Westport, Massachusetts, on June 12, 1951. Two tagged on September 30, 1949, and October 22, 1950, were retaken at New Jersey at Avon-by-the-Sea on November 24, 1949, and at Shark River on July 20, 1951. Two tagged on November 1, 1950, and July 10, 1951, were recaptured in Delaware at Indian River Inlet on December 6, 1951, and near Makon on January 10, 1951. Another tagged on August 28, 1950, was retaken on March 1, 1951, at Swan Point, Chesapeake Bay.

Although these data on migration are relatively few it is in line with our findings regarding the existence of two races which seasonally mingle in the Coney Island to Jones Beach area. Some are apparently of the Hudson River stock and relatively fewer are of the Chesapeake-Delaware type, the migratory path of which was worked out by Merriman (1941).

New Jersey. Of the bass originally tagged in the fall (September 17 to November 30, 1950, '51 and '53) along the northeast New Jersey coast from Sandy Hook to Manasquan, 15 were subsequently recovered to the southward either in known overwintering areas such as Toms River, Barnegat Bay or Great Bay or had moved southward to Delaware Bay (3 specimens) or Chesapeake Bay (4 specimens). Six bass 14 to 16 inches long of a group originally tagged in northeast New Jersey (Asbury Park, 5 specimens, and mouth of Shark River, 1 specimen) during the period October 26-November 25, 1948 and 1950, were recaptured the following spring in the Hudson River from the area between Nyack and Piermont, New York. These may have overwintered in the Hudson River or have been part of a breeding migration.

Four were also tagged and recovered in summer (July 11-August 12, 1951) along the northeast coast of New Jersey. Those tagged at Deal (1 specimen) and Bradley Beach were recovered later that summer or early fall (August 6 to September 15, 1951) at nearby Asbury Park, Elberon, and Shark River. Another specimen tagged at Barnegat Jetty in late August, 1950, was recaptured at a short distance to the northward, Bay Head Canal, October 19, 1950. The inference from the small sample is that a proportion of New Jersey stripers remain in the same or a nearby area through the summer.

Delaware Bay. Ten returns are available from striped bass 9 to 12 inches long tagged originally in Delaware Bay, at Salem Cove, Salem, New Jersey. Six tagged from September 6 through November 1, 1950, 1951 and 1952 were recovered from Delaware Bay during the period January 14 to March 18. The captures occurred the winter or early spring following the release in each case. The returns were from Delaware Bay off the region between Little Creek and Bowers, Delaware, and were probably taken in the short winter fishery which has long been known in Delaware Bay. Three returns originally tagged at Salem were from the Chesapeake Bay. One tagged at Salem Cove June 4, 1951, was recaptured on October 14, 1951, in upper Elk River, which is near the western end of the Chesapeake and Delaware Canal. Another return from Millers Island in upper Chesapeake Bay recaptured on April 1, 1952 (originally tagged Salem Cove, October 27, 1951) also might have used the Canal. The third return first tagged at Salem Cove September 17, 1951, was recaptured in Chesapeake Bay off Matapeake on February 10, 1952.

Chesapeake Bay. Twenty recoveries in Chesapeake Bay and tributaries of stripers mostly 8 to 10 inches long marked in the spring (3), summer (3) and fall (14), 1949, were all made from within Chesapeake Bay or one of its tributaries and none marked in Chesapeake Bay were recovered from outside the Bay.

Massachusetts. Five recoveries of bass originally tagged in Massachusetts (September 18 to October 13) were all made south of the area and although the data are sparse, confirm the previous findings of Merriman (1941). Recoveries were made in Delaware Bay (January 25); Toms River, New Jersey (February 10); East Hampton (November 2) and Patchogue (November 12), Long Island; and one tag was recovered from the fish market, Stamford, Connecticut.

Two other Massachusetts returns are available. One 21-inch specimen tagged at Plum Island River, Newburyport, Massachusetts, on ay 23, 1952, was retaken in the Merrimac River on June 16, 1952. nother 14-inch specimen, tagged on May 6, 1951, at Wareham, Maschusetts, was retaken on March 30, 1952, at Salt Pond, Rhode Island.

CONCLUSIONS AND SUMMARY

The presence of one race, such as the Hudson race, located in the nter of the migratory range of another race such as the Chesapeake, ith a segment of the latter regularly migrating north to Rhode land, Massachusetts, and perhaps farther, requires explanation. A udy of tag returns indicates that in the late spring the Hudson race, a portion thereof, regularly moves to the western end of Long sland Sound. This Hudson stock seldom goes eastward beyond Fairort, Connecticut, or Northport, Long Island. Some also migrate out f the mouth of the Hudson River but do not often go father east long the south shore of Long Island than Jones Beach. In the fall here is a reverse movement into the Hudson River where the striped ass is found in numbers as far upstream as Stony Point. Actually it s this latter or upstream migration which is proven beyond doubt by ag returns.

Merriman (1937 arnd 1941) showed that striped bass of the Chesaeake race apparently migrate independently and strike off the New ersey shore, the south and southeast shore of Long Island where conentrations are known at points such as Montauk. From there they nove almost directly north to such well-known bass areas as Niantic iver, Point Judith, Rhode Island, and northward. During the fall outhern migration, it seems that a relatively few individuals of the hesapeake race get into the western end of Long Island Sound and a ew enter the mouth of the Hudson River. Most make their way southward to the New Jersey coast and the Delaware and Chesapeake Bays.

In the present study the returns from bass tagged in Massachusetts generally confirm the findings of Merriman (1941) of a southward coastwise migration in the fall.

Racial studies using fin ray counts confirm previous findings of an upstream race which is found in the Hudson at Haverstraw and northward. The lower Hudson, south of Haverstraw, has a population of young which at least in some years are derived from Chesapeake stock or bass with similar characters. It seems improbable that the upstream stocks in the Hudson River are a result of modification due to different external physical conditions. On the basis of the character index (Table 4) the Hudson race is separated 70 per cent from the Chesapeake race. The dorsal count gives the best separation of any single character; the count is 11 more often than 12 in the Hudson race and the reverse in the Chesapeake race.

A sample of 35 striped bass, ten to twelve inches long, taken on May 11, 1953, at Point Saconnet, Rhode Island, had a mean of 56.5 for character index and had other counts which indicate without reasonable doubt that these fishes were not of upper Hudson River origin, but were probably of Chesapeake or Delaware stock.

Evidence is presented of a possible endemic stock in Nova Scotia which is close in some counts to southern populations in Albemarle Sound and the Edisto and Santee rivers, South Carolina. The Albemarle Sound population seems to be endemic or nearly so although it is closely related to Chesapeake stock. The South Carolina stock is virtually 100 per cent separable from the Albemarle Sound stock on fin ray and low lateral line scale counts. There is additional evidence of subraces within Chesapeake Bay and there is a hint that upstream populations may differ in having lower counts.

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DISCUSSION

DISCUSSION LEADER WALLACE: Have you made any attempt to analyze stocks of fish after they have grown sufficiently to start to move, in an effort to detect the origin of the stocks in any given spot, using these basic data that you have collected?

DR. RANEY: Yes, we have, Dave.

For example, a week ago I visited with Jim Watson down at Rutgers, and we anged a "task force" and went down in southern New Jersey and obtained 57 ge striped bass, from 1½ to 6½ pounds. We made tests on these fish, and they ed up with the Chesapeake Bay stock. In other words, the frequency distribution s identical with the frequency distribution we had previously while working on ing fish of known origin from Chesapeake Bay. We can say with confidence t this stock of fish—from the Mullica River, New Jersey—were of Chesapeake y stock, and we now know that they have moved out of there and found that y have undoubtedly moved farther north.

This is well known, that a stock of fish produced in one area like Chesapeake y will contribute to a fishery which may operate many miles distant, h as Montauk Point, Massachusetts, and even off of Maine.

DR. LLOYD L. SMITH, JR. (Associate Professor, Institute of Agriculture, Uni- rsity of Minnesota, St. Paul, Minnesota): Have you any data on the relative undance of these various stocks, and if so, do they vary simultaneously?

DR. RANEY: Actually, no adequate sampling method is available to measure the e of these stocks.

In general, along the Atlantic Coast, the Chesapeake Bay area produces most the striped bass. I can say that without fear of contradiction. The Hudson ver stock is important mostly as a local fish in the western quarter of Long land Sound, and here it is of great importance because there are many people o fish out of New York City. They don't all fish for striped bass, but a great any do. So we do know that these local stocks, like the Hudson stock, are of eat importance, especially for the sport fisher.

In this striped bass program we are trying to set up sampling methods along e coast so that we will get some indication of the strength of the various year asses in the same summer the year class is produced.

At the moment the method is to wait until the year class comes into the fishery, an age of 2 years, when the fish are about 10 inches long, or an age of 3 or 4 ears, when they are 16 to 18 inches long. Then, by working back, if we have a od catch, we can say that, well, the 1942 year class was a good one, or the 1951 ar class was. We are trying to bring that up to date, to make better predictions, possible.

DR. WILLIAM SHELDON (Massachusetts Cooperative Unit, Amherst, Mass.): Ed, your introductory remarks you made some comment about the populations of riped bass, to the effect that you thought they were in better shape than in '34. ould you care to elaborate on that?

DR. RANEY: I think most of you remember that back in 1934, in Chesapeake ay, the striped bass fishing was lousy. In 1936 a perfectly tremendous number f bass came into the catch. My figures aren't fresh in my mind, but where one ad been caught in 1934, in 1936 they caught thousands, so that was a tremen- ous year class. The 1936 year class was the one which actually started the striped ass on the comeback trail.

We have had a succession of good year classes, not every year, of course, but 940 was fairly good, and 1942, and certainly in recent years the year classes have een good. I know from experience that this last summer there was a terrific catch f young in the Patuxent, the Rappahannock, the James and the York Rivers, in hesapeake Bay, in the Hudson River and in Albemarle Sound. I should say that ny studies were done in September, when these young were about 3 inchs long, o I can say with fair confidnce that two years from now the fishing is going to be retty good in Chesapeake Bay, off One O'Clock Point, off places in New Jersey nd off Massachusetts, because the 1953 year class was a good one.

However, we still don't have adequate sampling methods for making precise redictions, and that is one of the things I hope the various states involved in his program will work out.

Incidentally, the states that now have research programs, or will, shortly, are Massachusetts, Connecticut, New York, New Jersey, Maryland, South Carolina and —believe it or not—Florida. There is an endemic population of striped bass in St. Johns, Florida, which is important to the sport fisherman.

The Charles H. Gilbert of the Pacific Oceanic Fishery Investigations. Photograph taken in San Pedro after alteration, which included the addition of a 28-foot amidships section.

TUNA BAIT SURVEY

In the Marquesas and Tuamotus

By WILLIAM F. ROYCE
Fishery Research Biologist
Pacific Oceanic Fishery Investigations

HERE was good tuna bait in the Marquesas, but in the Tuamotus was scarce and difficult to catch. his was the conclusion reached after reconnaissance by scientists and shermen from the Pacific Oceanic ishery Investigations during a 10-ay visit to the islands with the ves-el *Charles H. Gilbert*. The baiting n the Marquesas was similar to that ound by the *Hawaiian Tuna* and the *hallenger* which fished the area in arlier years.

Sailing from San Pedro on Febru-ry 18, 1954, the *Gilbert* fished tuna ongline gear south from California cross the Equator and then went vest in order to refuel at Tahiti. The irst stop was in the Marquesas, vhich are about 3,000 miles south-vest of California at approximately 0° S. latitude. They are high vol-anic islands, extremely rugged, with ertical cliffs rising from the ocean around most of their shores. Admin-stered by the French government rom headquarters in Tahiti, they are nhabited by only about 3,000 peo-le, whose principal occupation is growing copra.

Baiting in the Marquesas

The *Gilbert* dropped anchor in the beautiful horseshoe-shaped bay at Taiohae on the island of Nuku Hiva just at dark on March 20. Early the next morning we found small bait fish abundant along the beach and actually caught 335 scoops with a 40-fathom beach seine 9 feet deep. After catching these and bailing them alive out of the net because we had no reason to keep them (we were not equipped for live bait tuna fishing), we scouted the rest of the beach and estimated that we could have caught 1,550 scoops more in schools of worthwhile size.

About 80% of this bait was a miniature herring called "sardine" by the local people.. We measured several hundred which averaged 3½ inches long. In some schools these were mixed with goatfish of the same size.

The next day we scouted Taipi Bay, about 10 miles to the east on the same island. This is a little larger bay at the mouth of a stream and here we found another excellent school of the sardines. It was in about 12 feet of water, which was too deep for our seine, but it was estimated to contain at least 800 scoops. Other smaller schools were seen, but only about 30 scoops were actually caught along the beaches.

Later that day we visited the island of Ua Pu. This island is ever rockier than Nuku Hiva and has only a few tiny beaches, none of which are well protected from the swells. Here we found the same sardine, but did not catch any because these schools were in 12 to 15 feet of water and the surf running on the beach was too heavy to permit the use of our beach seine.

This Marquesan sardine, said by the natives to be present all of the time, unquestionably is the sardine which other vessels have found in good quantities on most of the islands at this season of the year. However, they may not always be abundant because we have one report of a vessel which was unable to locate bait in the Marquesas during the middle of July.

In addition to the sardines, there were signs of other species suitable for bait. The goatfish have been mentioned and a few hundred scoops could have been taken. In addition, we saw some small jack mackerel or scad schooled around the wharf in Taiohae Bay and numerous signs of unidentified schooling fish in the deeper waters of the bay.

Three different kinds of nets should take almost any of these fish. Our bait seine, which is 9 feet deep and 40 fathoms long, was almost ideal for seining the sardines on the beaches. A similar seine suitable for 12 to 20 feet of water would take them in the deeper waters off the beaches, particularly where heavy surf prohibits working too close in. The third net ought to be a lampara

Reprinted from PAN AMERICAN FISHERMAN, August, 1954

The piherere of the Tuamotus, fairly abundant but small and hard to catch. This little round herring is similar to the Hawaiian piha, which must be used during the first day after capture.

type which could be pursed around the larger, faster swimming schools in the deeper waters of the bays.

The sardines seemed to be a hardy bait fish and our Hawaiian fishermen judged it would be satisfactory tuna bait. It was vigorous in the seine and did not tend to suffocate easily, nor did it lose a great many scales. We did not try to keep it in the tank to check its hardiness. Another vessel, which caught more than 1,000 scoops at the island of Hiva Oa, found that most of the bait died in about two days. However, we have no information on whether it was handled carefully or not.

Although we found this bait abundant in the bays we visited, there are too few bays to provide bait for many clippers. The islands are small with a land area less than 10% of that of the Hawaiian Islands, which support only about 25 sampans. The charts show less than 20 miles of beach and shoal areas where seining appears practical. (This is only about 1/6 of the shore line of the Gulf of Nicoya.) The rest of the shore is lined with rocks and precipitous cliffs.

Baiting in the Tuamotus

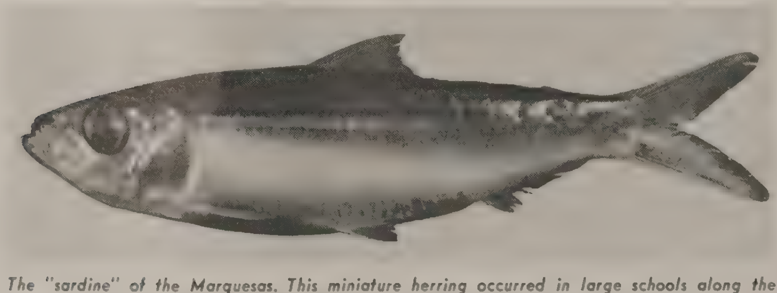
When we reached the Tuamotus, we found the baiting conditions much different. These are all low coral atolls situated about 400 miles southwest of the Marquesas. Many of them have navigable lagoons which reach 20 by 40 miles in size, and thus there is an enormous area where bait fish might occur.

We visited the atolls of Raroia, Makemo, Raraka, and Fakarava. In all of these except Raraka the passes were navigable by the *Gilbert* and we entered the lagoons and anchored. In Raraka it was reported by the natives that the copra schooner came in, but the chart was not detailed enough for us to try it. In all of these atolls the lagoons ranged from 100 to 200 feet in depth, but were sprinkled with coral heads, reaching almost to the surface. They were navigable in good light, however, when the coral heads could be seen to a depth of 30 feet or more in the clear transparent water. We took the *Gilbert* around some of the lagoons but mostly we scouted from a skiff and from shore.

Plenty of bait fish species were found, including goatfish, mullet, aholehole, jack mackerel, and a small round herring. However, none of these occurred in large schools in good seining areas. Some bait could be had, but from our experience a crew would be lucky to catch more than 20 or 30 buckets in a day's baiting. Strangely, the sardine so common in the Marquesas does not occur in the Tuamotus. None of the native fishermen recognized it.

The mullets and goatfish were scattered all around the edges of the lagoons in amongst coral heads on sandy or coral bottom. Here they usually escaped our seine or our net fouled so thoroughly on the coral that we could not move it.

The best bait was probably the small round herring which is called piherere by the natives, but it wouldn't be easy to catch it. We saw it commonly in schools of from 10 to perhaps 50 scoops around the coral heads in the lagoons and saw several schools of skipjack or yellowfin feeding on them. These piherere would be extremely difficult to catch around the coral heads, the sides of which are usually vertical for 20 to 40 feet and then slope precipitously into the deeper water. We never found this species in a good seining location, but in running over one lagoon with the *Gilbert* we picked up two echoes on our sounding machine which probably were from this species at a level of 30 to 40 feet in approximately 100 feet of water. Here they might be taken wi a purse seine.



The "sardine" of the Marquesas. This miniature herring occurred in large schools along the beaches in 3 to 15 feet of water. More than 1,000 scoops could easily have been caught in Taiohae Bay when the Gilbert stopped during March.

Besides being difficult to catch this species may not be satisfactory bait because it is so small and delicate. All of the piherere seen would go through the ¼-inch square mesh of our bait seine. The schools were usually of mixed sizes, 1¼ to 2 inches in length, and the larger ones were frequently fully mature males and females, so we presume that they do not attain a much larger size. It is similar to the Hawaiian piha, which must be used during the day after capture.

We tried night lighting in all of the lagoons except Raraka with a small trap especially designed for the collection of scientific specimens. This trap took a few piherere, but at no time did we see enough fish schooled around the light to indicate that a larger net might be worthwhile. Night baiting would probably not be very productive.

Of course, there are many islands in the Tuamotu group which we did not visit, but we found that the fish populations in the four that we did visit were very similar and probably baiting in the other lagoons is not much better. This guess is supported by a report from another vessel, which stopped at Rangiroa, one of the larger atolls, and found no bait in two days' scouting. Thus, we conclude that bait is much harder to catch in the Tuamotus than in the Marquesas.

Tuna in the Marquesas

Not only is bait available in the Marquesas but so are tuna. While approaching and leaving the islands we found plenty of birds working over fish schools, some of which were seen to be 10- to 30-pound yellowfin. Working flocks were especially common just south of Ua Huka and running south from Ua Pu we saw 19 large flocks in 1½ hours—which is more per hour than we have seen off Hawaii in months of scouting.

Yellowfin and skipjack have been fished off the Marquesas at this season in other years. Good catches have been made, but also many wild schools have been reported along with poor fishing despite many bird signs and schools of fish.

So no guarantees about the fishing in the Marquesas can be made. Bait in good quantities for a few boats has been available in three different years during March, but bait was hard to find in one year during July. Tuna schools have been plentiful but wild during March. The possibilities of a paying trip during the early part of the year look better in the Marquesas than in the Tuamotus.

Reprinted from PAN AMERICAN FISHERMAN, August, 1954

BIBLIOGRAPHIC SOURCES FOR FISHERY STUDENTS AND BIOLOGISTS

Leslie W. Scattergood

U. S. Department of the Interior, Fish and Wildlife Service
Boothbay Harbor, Maine

printed from Volume 83 (1953), Transactions of the American Fisheries Society.
Published 1954. Printed in U.S.A.

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LESLIE W. SCATTERGOOD

U. S. Department of the Interior, Fish and Wildlife Service
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INTRODUCTION

To review the literature concerning a particular field of fishery biolo
and to keep abreast of recent developments are formidable problems, for t
results of research have been published in numerous journals and in vario
languages for several centuries. Fortunately, there are bibliographic a
abstract journals, compendia, and special bibliographies, which are of v
uable assistance to the research worker. The purpose of this paper is
present an annotated list of some of these research aids. Other bibliograph
references—textbooks, scientific expedition reports, and scientific pape
published in various journals or series—have been omitted, since they a
widely known and used by all students and research workers.

I have included both fishery literature and zoological literature pertaini
to fishery or to related studies. Little has been included about insec
birds, and mammals, all of which are treated by special bibliographic
abstracting services, nor has detailed information on the literature
physiology, chemistry, physics, and allied subjects been included, althou
those branches of science often have important roles in fishery research.

In preparing this paper, I have obtained valuable data from Roger
Smith's *A guide to the literature of the zoological sciences*, Burgess Pub. C
114 pp., 1945, a comprehensive and valuable account of the sources
general zoological literature. This article can be considered as a spec
elaboration of Smith's publication. Included herein are more detailed d
criptions of certain of Smith's references, together with others of particul
interest to fishery workers, which were omitted from Smith's work.

The value and accuracy of the literature aid depend upon the thoroug

s of the compilers and editors and never is the literature covered com-
tely and without error. In using the following listing of journals,
nographs, . . . the research worker should realize that omissions and in-
uracies, although negligible, almost surely occur.

BIBLIOGRAPHIC JOURNALS

Bibliographies represent the results of the collection and compilation of
literature references. Several serial publications exist or have existed as
liographic journals to compile references to biological papers and so
ke them available to research workers. As these journals are of consider-
le value to biologists, I have in the following account given brief notes
each serial and, for some journals, an illustration of the various subjects
which references are shown.

Bibliographic Index. (1937–   ). This cumulative bibliography of
liographies appears quarterly. More than 1,500 periodicals are examined
ularly, and references are made to those articles which contain bibliog-
phies. Complete or comprehensive bibliographies are starred. The index
by subject only. The annual volume for 1949, which contained material
m the June, September, and December issues, plus additional material,
s pertinent references under Biology, Fishes, Natural History, Marine
ology, Ocean, and Zoology.

Bibliographica Oceanographica. (1929–   ). (Vol. 16, 1943, re-
ived in 1950). This serial developed from Giovanni Magrini, 1929, *Essai*
une bibliographie général des sciences de la mer, année 1928. References
e compiled from over 100 journals. The text is printed in either Latin or
alian, but the references are given in their original languages. Volume 15,
42, was found to have the references classified in the following categories:
General; 2. Physical Oceanography; 3. Biological Oceanography; and
Fishing. Under General are listed: Navigation; Marine Works, and
thers. The Physical Oceanography section is subdivided into further
tegories: General; Marine Geology; Marine Geography; Marine Chem-
try and Physics; Dynamics of the Sea; and Geophysics. Subdivisions
der Biological Oceanography include: General; Methods, Anatomy and
hysiology of Marine Animals; Botanical Anatomy and Physiology;
eproduction; Growth of the Embryo and Body Growth; Biochemistry;
cology; Plankton and Benthos; Systematic and Descriptive Zoology,
otany, Paleobiology, and Phylogeny. The Fishing section contains the
bdivisions: General; Fishery Economy and Legislation; Application of
iology to Fishing; Fishing Ports; Fishing Methods and Gear; Fishing
ocalities; Fishery Products; Nutritional Value of Fishery Products; Mar-
ets; Fishery-Products Industries and Commerce in Various Regions; By-
roducts of the Fisheries; and Preservation. Most of the above subdivisions
re broken down into further classifications. In all cases the numbers of
eferences are large.

Bibliographia Zoologica. (1896–1934, suspended 1916–1920). This serial was dependent upon the Concilium Bibliographicum for referenc In the 194 pages of Volume 43, 1934, the following divisions are consider of interest to fishery biologists: Paleontology; General Biology; Micr scopy, Preservation; General, Periodical, and Society Publications; M seums, Stations, and Aids to Study; Collected Publications and Historie Physiology, Embryology, Anatomy, Ecology, Economic Zoology, and Hi tology; Zoogeography; Invertebrata, and Protozoa—Mammalia—Biman

Journal of the Society for the Bibliography of Natural Histor (1936–). According to Volume 1, Part 2, this English organizati "is a scientific society instituted for the study of the bibliography of branches of zoology, botany and geology". Volume 1 has 12 parts includi 488 pages. Volume 2 has 5 parts to date (September 1949), including 1 pages. This journal has published some historical items on natural histor but few detailed bibliographies.

Zoological Record. (1864–). This journal is most important f all zoologists. Published by the Zoological Society of London, it is so w known and readily available at most scientific libraries that a detail discussion of it is unnecessary.

Abstract Journals

The above-mentioned bibliographic journals give only references to t scientific literature. Abstract journals, such as the seven listed below, pu lish summaries or reviews of the more important papers and often al include some bibliographic references.

Berichte über die wissenschaftliche Biologie. (1926–). Ba 61, 1943, the most recent available, was examined. Some divisions of possib interest to fishery workers follow: General; Methods; Morphology Animals; Biochemistry and Physiological Chemistry; Metabolic Physiolo of Animals; Stimulatory Physiology of Animals; Developmental Phy ology of Animals; Evolution Research; General Biology; Biological Geo raphy; Hydrobiology (including fishery biology); Symbiosis and Paras ism; Plant and Animal Diseases; Systematic Monographs. This serial published monthly.

Biological Abstracts. (1926–). This is the most important a stract journal for zoologists. Like the Zoological Record, it is so well know and so readily available that a discussion of its contents is unnecessar It is sponsored by the Union of American Biological Societies and is pu lished monthly.

Commercial Fisheries Abstracts. (1947–). This monthly "sur mary of important developments for the fishery industries" is published the Fish and Wildlife Service, U. S. Department of the Interior. The a stracts are printed in the shape of 3- by 5-inch cards, four to a page. T cards can be cut out and filed. In addition to the abstracts, a small bibli graphic section lists publications of secondary importance. A typical issu ume 3, No. 4, April 1950, had 40 abstracts and 51 bibliographic referes.

Vorld Fisheries Abstracts. (1950–). This bi-monthly review of ınical literature on fisheries and related industries is published by the ited Nations' Food and Agriculture Organization. The abstracts are ilar in form to those of Commercial Fisheries Abstracts and are derived gely from that publication. English, French, and Spanish editions are ilable. Volume 1, No. 1, contained 63 abstracts in addition to a 2-page echnological News" section which was devoted to notes on the results of ublished research.

entralblatt für Zoologie, allgemeine und experimentelle Biologie. 12–1918). This was a continuation of *Zoologisches Zentralblatt* (1894–12) and *Zentralblatt für allgemeine und experimentelle Biologie* (1910–12). The references in the last volume (No. 6) were arranged by phyla d classes and also by numerous divisions of which the following are imrtant to fishery students: Bibliography; Ecology; Geographic Distribun; Oceanography; Marine Fauna; Fresh-water Fauna; Fishery Biology; d Nature Conservation.

Zoologischer Bericht. (1922–). This serial classifies, lists, and stracts zoological publications. Section A11, Ecology, Ethnology, and the ctions on Mollusca, Crustacea, and Pisces are of special interest to fishery idents. It has a detailed index by subject and genus. Band 55, 1943–44, has 1,764 abstracts.

Zoologischer Jahresbericht. (1879–1924). This journal, published the Zoological Station of Naples, included bibliographies and abstracts ted by phyla and (in earlier editions) also by general subject. The reews or abstracts of the most recent findings in each animal group were esented by authorities in that particular field. The last number, published 1924, covered the year 1913.

JOURNALS WHICH INCLUDE BIBLIOGRAPHIES OR ABSTRACTS

In addition to those which are devoted entirely to bibliographies or stracts, there are other journals which, incidental to scientific papers, clude references or reviews of current literature. Such journals are exemely valuable, since they often publish these data several years before e bibliographic or abstract journals are able to do so. A list of journals hich generally contain notes on current literature follows:

Aarsberetning vedkommende Norges Fiskerier. Since 1937, a list fishery literature has been published in the annual report of Norwegian sheries. The first publication, by Einar Kofoed, covered the period 1880–936 and is found in the report for 1937, Nr. 6. A typical issue, that appearg in the report for the year 1947, classified fishery articles under the ree main divisions of Marine Fish and Fisheries, Fresh-water Fisheries, nd Whaling and Sealing. These divisions were subdivided into various iological, technological, and economic categories.

American Midland Naturalist. (1909–). A bi-monthly journal Volume 44, No. 1, July 1950, had 19 reviews of new biological books.

American Naturalist. (1867–). A bi-monthly serial, this journa contains a "Reviews and Comments" section dealing with current publ cations.

American Scientist. (1913–). This quarterly serial is publishe by the Society of Sigma Xi. Volume 38, No. 3, July 1950, had 19 review of new books in "The Scientist's Book Shelf" section.

Annalen der Hydrographie und Maritimen Meteorologie. Zeitsc rift für Seefahrt- und Meereskunde. (1873–1943). Heft 11, for th year 1943, contained 100 bibliographic references listed under: Instrumer and Apparatus Information; Astronomy; Terrestrial and Astronomica Navigation; Descriptions of Coasts and Harbors; Vessel Operation an Vessel Construction; and Miscellaneous.

Archiv für Fischerei-Wissenschaft. (1948–). This publicatio is sponsored by the Institut für Küsten- und Binnenfischerei der Bunde anstalt für Fischerei and the Deutsches Hydrographische Institut, both Hamburg. Jahrgang 2, Heft 1/2, had reviews of five books on fishery an related subjects.

Archiv für Hydrobiologie. (1893–). From 1893 to 1905, th German serial was known as *Forschungsberichte aus der biologischen Sta tion zu Plön.* Band 42, N. F., Heft 4, 1949, was examined. Eight book were reviewed and 353 references were given to recent hydrobiologica literature.

Biological Reviews. (1923–). This quarterly journal, publishe by the Cambridge Press at London, contains reviews and summaries recent biological researches.

Biologisches Zentralblatt. (1881–). This monthly journal ha reviews and summaries of books and papers. The 10 numbers of Band 6 1949, had 21 reviews.

Biologist. (1916–). This quarterly journal is published by Ph Sigma Society. Volume 31, No. 3, February 1949, had 77 reviews of ne books.

Commercial Fisheries Review. (1938–). In addition to article about the commercial fishing industry, this monthly publication of th Fish and Wildlife Service, U. S. Department of the Interior, has a sectio which lists and abstracts recent fishery articles. The May 1950 issue in cluded 32 abstracts of fishery publications.

Copeia. (1913–). Published by the American Society of Ichthy ologists and Herpetologists, this quarterly journal has a section devoted t reviews and comments on recent literature. The June 30, 1950, issue con tained reviews of nine books on fish and reptiles.

Ecology. (1920–). This quarterly journal, devoted to all phase of ecological biology, is published by the Ecological Society of America n book reviews and book notices are presented, the latter being more reviated. Volume 31, No. 1, January 1950, had 6 book reviews and ook notices.

ie Fischwirtschaft. (1949–). This German monthly periodical, lished as *Fischereiwelt* until September 1952, is of interest primarily hose concerned with the marine fisheries. Heft 2, February 1950, of the nd volume, had reviews of three new fishery books.

ood and Agriculture Organization of the United Nations, Fish-es Bulletin. (1948–). In Volume 3, No. 1 (January-February 0), under "Notes on Publications," there were 18 abstracts of fishery cles.

Iydrobiologica. Acta Hydrobiologica, Limnologica et Protisto-ica. (1948–). This quarterly journal is devoted to investigations he general field of zoo- and phytobiology of marine and fresh-water ns. Volume 2, No. 3, 1950, had an annotated bibliography of 23 cles.

nternationale Revue der gesamten Hydrobiologie und Hydro-phie. (1908–1943). The volume for 1938 has reviews of 72 articles l books. Some of the earlier volumes contain bibliographies and sum-ries on special problems and references to current literature. Originally oted to studies of the physics and biology of all waters, this periodical ely contained papers mostly on limnology.

ournal du Conseil Permanent International pour l'Exploration de Mer. (1926–). This serial includes both reviews and a current liography of the science of the seas. It is, perhaps, the fishery biologist's st valuable source of references to recent literature. Volume 16, No. 1, ntained reviews of 12 publications and 789 bibliographic references.

Journal of Animal Ecology. (1932–). In this serial, the British ological Society includes abstracts of all publications on the animal logy of the British Isles which are brought to its attention. Volume 19, . 1, May 1950, had four reviews and a classified, abstract list of 120 es.

Journal of Ecology. (1913–). This serial has papers and biblio-phies on plant ecology, including phases of limnology and oceanography. lume 38, No. 1, July 1950, had 6 reviews and 93 references to papers ecological interest reviewed by the British Ecological Society.

Nature. (1869–). This English scientific journal has a monthly pplement listing recent scientific and technical books. In Volume 166, . 4213, July 29, 1950, there were listed 14 books on general biology, tural history, botany, and zoology.

Progressive Fish-Culturist (1938–). In addition to articles on h culture and fresh-water fish management, this journal of the Fish and ildlife Service, U. S. Department of the Interior, often has abstracts and views on recent fishery publications. The January 1950 issue included four abstracts and the "Clearing House" section carried two bibliographi references to recent articles.

Quarterly Review of Biology. (1926–). This periodical contain a section which reviews new biological books. In Volume 24, No. 2, Jun 1949, there are reviews and brief notices of 80 publications in the whol field of biology.

Science. (1883–). Published weekly by the American Associatio for the Advancement of Science, this journal has "Book Reviews" an "Scientific Book Register" sections. It also lists publications recently received in its offices. This serial covers the entire field of science; there ar many references of interest to fishery workers.

Transactions, American Geophysical Union. (1931–). This bimonthly journal of the American Geophysical Union has a review, abstract and bibliography section concerned with recent articles on various geophysical subjects. Volume 31, No. 2, Part 1, for April 1950, had 11 bibliographic references to meteorology, 50 to oceanography, and 48 t hydrology.

Zeitschrift für Fischerei und deren Hilfswissenschaften. (1893–) This German fishery serial contains abstracts of fishery articles, primaril on fresh-water studies. Band 36, Heft 5, has reviews of 9 publications

COMPENDIA—HYDROBIOLOGY AND FISHERIES

As the zoological fields become more intensively studied and the literature more massive, a definite need arises for manuals which summariz the existing information. Such compendia, many of which are in German are also valuable because of their detailed bibliographies. There are four o prime importance to the fishery student. For the benefit of those who ma be unable to read the language but wish to consult the bibliographies, I have included English translations of the titles of individual publication in the three German compendia.

Die Binnengewässer. Seventeen volumes have been printed in thi series on inland waters, although not all are complete. These generall contain extensive bibliographies. The volumes are often catalogued i libraries under the editors E. Naumann and A Thienemann, rather tha by individual authors. Following is a list of the publications for which I have information:

Band 1. Die Binnengewässer Mitteleuropas (Inland waters of central Europe) 255 S., 1926.
Band 2. Bodenablagerungen und Entwicklungstypen der Seen (Bottom deposit and evolutionary types of lakes). 124 S., 1927.
Band 3. Die Tierwelt der unterirdischen Gewässer (Animals of subterranea waters). 176 S., 1927.
Band 4. Der Sauerstoff im eutrophen und oligotrophen Seen (Oxygen in eutrophi and oligotrophic lakes). 175 S., 1928.
Band 5. Das Leben der Wolga (Biology of the Volga). 162 S., 1928.
Band 6. Grundlinien der experimentellen Planktonforschung (Basic principles of experimental plankton investigations). ix + 100 S., 1929.

and 7. Die Biologie der Moore (The biology of bogs). 146 S., 1929.
and 8. Der Hochgebirgssee der Alpen (The high mountain lake in the Alps). 168 S., 1929.
and 9. Einführung in die Bodenkunde der Seen (Introduction to the study of lake bottoms). ix + 126 S., 1930.
and 10. Fischereibiologie der Alpenseen (Fishery biology of Alpine lakes). viii + 259 S., 1930.
and 11. Grundzüge der regionalen Limnologie (Fundamentals of regional limnology). xiv + 176 S., 1932.
and 12. Hydrochemische Methoden in der Limnologie (Hydrochemical methods in limnology). x + 173 S., 1932.
and 13. Kohlensäure und Kalk (Carbonic acid and lime). vii + 183 S., 1933.
and 14. Der Sauerstoffhaushalt der Seen (Oxygen economy of lakes). viii + 217 S., 1934.
and 15. Das Zooplankton der Binnengewässer (Zooplankton of inland waters). xii + 272 S., 1935.
and 16. Das Phytoplankton des Süsswassers (Phytoplankton of fresh water).
  Heft 1. iii + 342 S., 1938.
  Heft 2. Erste Hälfte, v + 366 S., 1941.
    Zweite Hälfte, x + 183 S., 1942.
  Heft 3. In press.
  Heft 4. In preparation.
and 17. Die wirtschaftliche und kulturelle Bedeutung der Binnengewässer (Economic and cultural significance of inland waters) xiv + 286 S., 1949.

ishes of the Western North Atlantic. This is a Memoir series of Sears Foundation for Marine Research, Yale University. Number 1, rt 1, Lancelets, Cyclostomes, Sharks, has been published and others are preparation. The first published work contains excellent bibliographies the subjects treated.

Handbuch der Binnenfischerei Mitteleuropas. This work on the and fisheries of central Europe has extensive bibliographies. In some raries these volumes are indexed under the editors, R. Demoll and H. N. aier. Six volumes have been published; information on them follows:

Band 1. Das Wasser und seine Bewohner (Water and its inhabitants).
  Die Gewässer Mitteleuropas. Ein hydrobiologische Charakteristic ihre Haupttypen (Waters of central Europe. A hydrobiological description of their principal types). S. 1–84, 1924.
  Die Mikroflora des Süsswassers und ihre Bedeutung für den Haushalt der Gewässer (Microflora of fresh water and its role in the aquatic community). S. 85–144, 1924.
  Die Nahrungstiere der Fische (Animal food of fish). S. 145–228, 1924.
  Die Fischfeinde aus der höheren und niederen Tierwelt (Enemies of fish from the higher and lower animal kingdom). S. 229–474, 1924.
  Verzeichnis (Index). S. 475–479, 1924.
Band 2B. Physiologie der Süsswasserfische Mitteleuropas (Physiology of the fresh-water fishes of central Europe). 340 S., 1936.
Band 3. Systematik und Biologie (Systematics and biology).
  Lieferung 1. Die Süsswasserfische Deutschlands. Eine tiergeographische Skizze (Fresh-water fishes of Germany. A zoogeographic sketch). S. 1–32, 1926.
  Lieferung 2. Einführung in die Systematik der Süsswasserfische Mitteleuropas (Introduction to the systematics of the fresh-water fishes of central Europe). S. 33–51, 1928.
  Lieferung 3. Die Stachelflossen (Acanthopterygii). S. 52–100, 1928.
    Die Weichflossen (Anacanthani). S. 101–110, 1929.

Die Plattfische (Heterosomata). S. 111–129, 1929.

Die Stichlinge (Gasterosteidae). S. 130–141, 1929.

Die Welse (*Silurus glanis* and *Ameiurus nebulosus*). S. 142–158, 1929.

Lieferung. 4. Der Flussaal (*Anguilla vulgaris*). S. 159–217, 1930.

Lieferung 5. Die Lachsartigen (Salmonidae) I. S. 218–370, 1937.

Lieferung 6. Die Lachsartigen (Salmonidae) II. Coregonidae. S. 371–501, 1941.

Lieferung 7. *Osmerus artedi*. S. 502–551, 1941.

Band 4B. Fischereiwirtschaft. I. Geschichte der Binnenfischerei.

II. Teichwirtschaft und kunstliche Fischzucht (Fishing industry. I. History of fresh-water fisheries. II. Pond management and artificial propagation of fish).

Lieferung 1. Die Geschichte der Binnenfischerei von Mitteleuropa (History of the central European inland fishery). S. 1–52, 1925.

Teichdüngung (Pond fertilization). S. 53–158, 1925.

Lieferung 2. Salmonidenzucht in Mitteleuropa (Salmon culture in central Europe). S. 159–348, 1931.

Lieferung 3. Karpenzucht (Carp culture). S. 349–406, 1934.

Lieferung 4. Teichwirtschaft und Geflugelzucht in ihren Wechselbeziehungen (Pond management and poultry breeding, their interrelations). S. 407–482, 1934.

Lieferung 5. Grundlagen der allgemeinen fischereilichen Produktionslehre (General principles in the field of fish production). S. 483–662, 1934.

Lieferung 6. Die Schleienzucht (Tench culture). S. 663–721, 1939.

Die Zucht des Zanders in Karpfenteichwirtschaften und in freien Kewässern (Culture of *Lucioperca* in carp ponds and in open waters). S. 722–748, 1939.

Lieferung 7. Die Hechtzucht (Pike culture). S. 749–787, 1940.

Die medizinische Blutegel und seine Bedeutung in der Wasserwirtschaft (The medicinal leech and its significance in the management of waters). S. 788–811, 1940.

Lieferung 8. Fischerei Futtermittelkunde (Study of fish foods). S. 812–922, 1945.

Band 5. Die Fischerei in den Fliessen, Seen und Strandgewässern Mitteleuropas (The fishery in the rivers, lakes and inshore waters of central Europe). S. 1–422, 1926.

Der Flusskrebs, seine Verwandten und die Krebsgewässer (The crayfish, its relatives, and crayfish waters). S. 423–524, 1926.

Perlen und Perlenmuscheln (Pearls and pearl mussels). S. 525–552, 1926.

Erganzungs-Band zu Band 5.

Lieferung 1. Netzkonservierung im Fischereibetrieb (Net preservation in the fishing industry). S. 1–99, 1941.

Lieferung 2. Die Wollhandkrabbe (The mitten crab). S. 100–140, 1942.

Band 6. Fischereischutz; Fischverwertung. Fischereirecht und Organisation (Fishery protection; fishery economics. Fishery regulations and organization).

Lieferung 1. Anlage und Betrieb von Fischpässen (Installation and operation of fishways). S. 1–137, 1924.

Lieferung 2. Die Reinhaltung unserer Fischgewässer (How to keep our fish waters clean). S. 138–221, 1926.

Die Reinigung von Abwässern in Fischteichen (Purification of sewage in fish ponds). S. 222–262, 1926.

Lieferung 3. Abwässerbeseitigung und Gewässerverunreinigung (Sewage disposal and water pollution). S. 263–287, 1928.

Toxikologie der Fische (Toxicology of fish). S. 289–342, 1928.

Lieferung 4. Die Erhaltung und Pflege der Fischgewässer (Maintenance and care of water for fish). S. 343–416, 1937.

Handbuch der Seefischerei Nord-Europas. This publication deals with the sea fisheries of northern Europe. Ten volumes have been printed. In most libraries the volumes are catalogued under the editors, H. Lübbert and E. Ehrenbaum. Information on the volumes follows:

nd 1. Naturbedingungen des Lebens in Meere (Natural conditions of life in the sea).
Heft 1. Die waagerechte Gliederung und die Tiefen des Meeres (Stratification and the depths of the ocean). iii + 23 S., 1949.
Heft 2. Die natürlichen Eigenschaften der Gewässer (Natural properties of water). iii + 37 S., 1949.
Heft 3. Die Bodenbedeckung der nordeuropäischen Meere (Bottom deposits of the North European seas). iii + 33 S., 1949.
Heft 4. Die festsitzenden Pflanzen der nordeuropäischen Meere (Sessile plants of the North European seas). iii + 54 S., 1930.
Heft 5a. Die Nahrung der Meerestiere (Nutrition of marine animals). I and II. iii + 85 S., 1950.
Heft 5b. Die Nahrung der Meerestiere (Nutrition of marine animals). III and IV. (In press).
Heft 6. Der Stoffhaushalt im Meere (Metabolism of the sea). iv + 37 S., 1933.
and 2. Die Seefische Nord-Europas. Naturgeschichte und writschaftliche Bedeutung der Seefische (Marine fishes of northern Europe. Natural history and economic importance of the marine fishes). x + 377 S., 1936.
and 3. Systematik und Biologie anderer writschaftlich wichtiger Meerestiere Nord-Europas (Systematics and biology of other economically important North European marine animals).
Heft 1. Wale, Robben (Whales, seals). v + 54 S., 1937.
Heft 2. Krebse und Weichtiere (Crustacea and Mollusca). vi + 147 S., 1929.
Heft 3. Seemoos (Bryozoa). vi + 34 S., 1938.
and 4. Die wichtigsten Fanggeräte (Principal fishing gears).
Heft 1/2. Schleppnetze. Waden (Drag nets. Haul seines). xi + 52 S., 1942.
Heft 3. Stehende Geräte und Treibnetze (Stationary gear and drift nets). xi + 48 S., 1940.
Heft 4. Angeln (Angling). iv + 48 S., 1935.
Band 5. Die Deutsche Seefischerei (German sea fishery)
Heft 1. Die Nordseefischerei (North Sea fishery). vii + 229 S., 1928.
Heft 2. Die Nordsee-Fischereihäfen (North Sea fishing ports). (In press).
Heft 3. Die Ostseefischerei (Baltic fishery). vii + 182 S., 1929.
Heft 4. Der Walfang (Whaling). iii + 33 S., 1928.
Heft 5. Der Walfang seit 1936 (Whaling since 1936). (In press).
Band 6. Die Seefischerei von Grossbritannien und Irland (Marine fishery of Great Britain and Ireland). xi + 334 S., 1929.
Heft 1. Geschichtliche Entwicklung der britischen Fischerei (Historical development of the British fishery).
Heft 2. Verwaltung und Regelung der Fischerei (Management and regulation of the fishery).
Heft 3. Betriebsarten und Fahrzeuge (Fishing methods and ships).
Heft 4. Fischereidistrikte und Fischereihäfen (Fishing districts and ports).
Band 7. Die Seefischereien von Frankreich, Niederlande, Belgien, Island (Marine fisheries of France, Holland, Belgium, and Iceland).
Heft 1. Die französische Seefischerei (French sea fishery). vii + 180 S., 1937.
Heft 2. Die niederländische Seefischerei (Dutch sea fishery). v + 104 S., 1933.
Heft 3. Die belgische Seefischerei (Belgian ocean fishery). iv + 39 S., 1932.
Heft 4. Die isländische Seefischerei (Icelandic ocean fishery). iv + 89 S., 1930.
Heft 5. Austern- und Muschelkultur (Oyster and mussel culture). iv + 64 S., 1932.
Band 8. Die Seefischereien von Norwegen, Dänemark, Schweden, Finnland, Russland, Estland, Lettland und Danzig (Marine fisheries of Norway, Denmark, Sweden, Finland, Russia, Estonia, Latvia, and Danzig).
Heft 1a. Die norwegische Seefischerei (Norwegian ocean fishery). x + 181 S., 1938.
Heft 1b. Der norwegische Walfang. Der norwegische Robbenfang (Norwegian whaling. Norwegian sealing). xii + 94 S., 1938.

Heft 2. Die dänische Seefischerei (Danish ocean fishery). v + 108 S., 1931.
Heft 3a. Die schwedische Nordseefischerei (Swedish North Sea fishery). (In press).
Heft 3b. Die schwedische Ostseefischerei (Swedish Baltic fishery). iii + 32 S., 1934.
Heft 4. Die Seefischerei von Finnland (Finnish sea fishery). iv + 73 S., 1934
Heft 6. Die Seefischerei von Estland und Lettland (Marine fishery of Estonia and Latvia). iii + 34 S., 1928.
Heft 7. Die Seefischerei von Danzig (Marine fishery of Danzig). iii + 34 S. 1931.

Band 9. Verwertung der Seefischereiprodukte (Utilization of marine fishery products).
Heft 3a. Bratfischhandel, a) in Grossbritannien (Smoked fish trade, a) in Great Britain). iii + 34 S., 1931.

Band 10. Förderung der Seefischerei (Promotion of the sea fishery).
Heft 4. Internationale Seefischereistatistik (International marine fishery statistics). iv + 41 S., 1928.

Compendia—General Zoology

Three other German compendia are also important sources of bibliographic material. All are concerned with the animal kingdom and contain sections of particular interest to the fishery biologist. The three are as follows:

Bronn's Klassen und Ordnungen des Tier-reichs wissenschaftlichen dargestellt in Wort und Bild. This valuable work, published by C. F. Winter, first appeared in 1859 and has not yet been completed. It deals with the classes and orders of the animal kingdom, is well illustrated, and has voluminous references.

Das Tierreich. Eine Zusammenstellung und Kennzeichnung der rezenten Tierformen. This series is edited by F. E. Schulze, W. Kükenthal, et alia, and is published by Walter de Gruyter and Co. Many of the parts have abbreviated bibliographies for each genus and species.

Kükenthal's Handbuch der Zoologie. Eine Naturgeschichte der Stämme des Tierreichs. This work on the natural history of animal groups contains valuable bibliographies.

Special Bibliographies

Usually one must gather the references from masses of scientific literature and compile his own bibliography; however, the research worker may be fortunate enough to find published a fairly comprehensive bibliography of his particular field of interest. A list of such specialized bibliographies, which deal with special fishery or related subjects and consequently are of interest to many fishery workers, follows:

Albee, Louise Rankin
1896. The Bartlett collection. A list of books on angling, fishes, and fish culture. Harvard Univ. Library Bibliographical Contrib. No. 51, 180 pp.

Allen, E. J.
1926a. A selected bibliography of marine bionomics and fishery investigations. Part I. Physical and biological conditions in the sea. Jour. Cons. Perm. Int. Expl. Mer, Vol. 1, pp. 77–96.

26b. A selected bibliography of marine bionomics and fishery investigations. Part II. Fishes and fishery investigations (plus addendum to Part I). Jour. Cons. Perm. Int. Expl. Mer, Vol. 1, pp. 173–193.

RICAN GEOPHYSICAL UNION

37–1941. Bibliography of hydrology (United States of America) for the years 1935 and 1936. 78 pp. (1937); for the year 1937. 68 pp. (1938); for the year 1938. 72 pp. (1939); for the year 1939. 86 pp. (1940); for the year 1940. 93 pp. (1941).

52. Annotated bibliography on hydrology, 1941–1950 (United States and Canada). Washington, U.S. Gov't. Print. Off., v + 408 pp.

NYMOUS

09. List of works in the New York Public Library relating to fishing and fish culture. Bull. N. Y. Pub. Library, No. 13, pp. 159–307.

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49. Bibliography on zoology. A source list up to 1948. Battelle Memorial Inst., Columbus, Ohio, 135 pp., mimeographed.

GHMAN,, J. L.

947. An annotated bibliography of oysters with pertinent material on mussels and other shellfish and an appendix on pollution. Texas A. and M. Res. Foundation, Agr. and Mech. Coll. of Texas, 794 pp.

949. An annotated bibliography for the student of Texas fishes and fisheries, with material on the Gulf of Mexico and the Caribbean Sea. Texas Game, Fish and Oyster Comm., 240 pp., mimeographed.

RD, HARRY R.

931. A selected bibliography of chemical literature pertaining to the fish industry. Cal. Fish and Game, Vol. 7, pp. 256–260.

NEY, WILLIAM GREENE

863. Bibliography of North American conchology previous to the year 1860, prepared for the Smithsonian Institution; Part 1, American authors. Smiths. Inst., Misc. Coll., Vol. 5, 650 pp.

1864. Bibliography of North American conchology previous to the year 1860, prepared for the Smithsonian Institution; Part 2, Foreign authors. Smiths. Inst., Misc. Coll., Vol. 9, 306 pp.

ECK, THORVALD

1880. Chronologisk fortegnelse over skrifter og afhandlinger om de norske fiskerier. Christiania, R. Hviids Enkes, pp. 1–26.

SGOED, D. MULDER..

1873. Bibliotheca ichthyologica et piscatoria. Catalogus van boeken en geschriften over de natuurlijke geschiedenis van de visschen en walvisschen, de kunstmatige vischteelt, de visscherijen, de wetgeving op de visscherijen, enz. Harlem, Loosjes, xxvi + 474 pp.

JCHER, DORRIS, MARTIN HEERDT, JR., and KATHRYN OSTERHARG

1949. Bibliography of the preservation of fishery products by freezing. Fish and Wildlife Serv., U. S. Dept. Interior, Fish, Leaflet No. 265, 151 pp.

RBINE, WILLIAM F.

1952. Doctoral dissertations on the management and ecology of fisheries. Additional listings—1952. Fish and Wildlife Serv., U. S. Dept. Interior, Spec. Sci. Rept.: Fish. No. 87, 44 pp.

RRIGAN, EDWARD J.

1947. Bibliography on the chemical nature of fish. Office of Tech. Serv., U. S. Dept. Commerce. (640 cards on microfilm).

RRIKER, M. R., M. F. BUELL, and E. T. MOUL

1950. A preliminary list of the literature on the ecology of the estuaries, with emphasis on the middle Atlantic coast of the United States. Zool. Dept., Rutgers Univ., New Brunswick, N. J., 52 pp., mimeographed.

ONSEL INTERNATIONAL DES RECHERCHES UNION GÉODÉSQUE ET GÉOPHYSIQUE INTERNATIONALE

1929. Bibliographie des marées (1910–1927). Bull. No. 12, 27 pp.

1931. Tidal bibliography. Bull. No. 17, 14 pp.

CONSEIL PERMANENT INTERNATIONAL POUR L'EXPLORATION DE LA MER
1903. Die Literatur der zehn wichtigsten Nutzfische der Nordsee in monographischer Darstellung. Publ. de Circonstance No. 3, 112 pp.

CORWIN, GENEVIEVE
1930. A bibliography of the tunas. Cal. Div. Fish and Game, Fish Bull. No. 22, 103 pp.

DAHL, SVEND
1910. Bibliotheca zoologica Danica 1876–1906. Fortegnelse over Danmarks zoologiske litteratur 1876–1906. Copenhagen, J. L. Lybeckers, xxii + 262 pp.

DEAN, BASHFORD
1916a. Bibliography of fishes. Vol. I, Authors A-K. New York, Am. Mus. Nat. Hist., x + 718 pp.
1916b. Bibliography of fishes. Vol. II, Authors L-Z. New York, Am. Mus. Nat. Hist., 702 pp.
1923. Bibliography of fishes. Vol. III, Indices, general bibliographies . . . addenda and errata of Vols. I and II. New York, Am. Mus. Nat. Hist., 707 pp.

FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS
1952. Fisheries technology literature. World Fish. Abstracts, Vol. 3, Suppl., 48 pp.

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1923. Bibliographia pathologiae piscium. Collegit atque edidit auxilio ministerii pro agricultura czechoslovakiae. Prague, Hopfer, pp. 187–263.

GRAHAM, MICHAEL
1929. Studies of age-determination in fish. Part II. A survey of the literature. Great Brit., Min. Agr. and Fish., Fish. Invest., Ser. 2, Vol. 11, No. 3, 50 pp.

GEYER, RICHARD A.
1950. A bibliography on the Gulf of Mexico. Texas Jour. Sci., Vol. 3, pp. 44–92.

GRIER, MARY C.
1941. Oceanography of the North Pacific Ocean, Bering Sea and Bering Strait: a contribution toward a bibliography. Univ. Wash. Publ., Library Ser., Vol. 2, 290 pp.

GURNEY, ROBERT
1939. Bibliography of the larvae of decapod crustacea. London, The Ray Society, 123 pp.

HACHEY, H. B., and A. L. MOOERS
1949. A bibliography of physico-chemical oceanography. Fish. Res. Bd. Canada, Manuscript Rept., Atl. Biol. Sta., No. 389, 73 pp., mimeographed.

HAWKINS, R. R.
1946. Scientific, medical, and technical books published in the United States of America 1930–1944. Washington, Nat. Res. Council, xv + 1,114 pp.
1950. Scientific, medical, and technical books published in the United States: supplement of books published 1945–1948. New York, R. R. Bowker, 514 pp.

HOPKINSON, JOHN
1913. A bibliography of the Tunicata. London, The Ray Society, 288 pp.

HORA, S. L.
1952. Bibliography of Indian fisheries literature published in the year 1951. FAO Indo-Pac. Fish. Council, Occ. Paper 52/11, 10 pp., mimeographed.

HUTTON, J. ARTHUR
1921. The literature of fish scales. Salmon and Trout Magazine, No. 26, July 1921, pp. 203–217.

INTERNATIONAL BOARD OF INQUIRY FOR THE GREAT LAKES FISHERIES
1943. Selected bibliography on the Great Lakes, their fishes, and fisheries. *In*: Int. Bd. Inquiry Great Lakes Fish., Rept. and Suppl., pp. 126–142.

JENKINS, JAMES TRAVIS
1948. Bibliography of whaling. Jour. Soc. Bibliography Nat. Hist., Vol. 2, Pt. 4, pp. 71–166.

KARRICK, NEVA
1948. The nutrition of fish in hatcheries. A literature review. Fish and Wildlife Serv., U. S. Dept. Interior, Fish. Leaflet No. 325, 23 pp., mimeographed.

e, Ruth V.
52. Sources of information concerning the commercial fisheries. Fish and Wildlife Serv., U. S. Dept. Interior, Fish. Leaflet No. 362, 23 pp., mimeographed.

, A. Myra
37. An abridged checklist and bibliography of West North American marine Mollusca. Stanford Univ. Press., 87 pp.

er, Karl F., and Charles K. Fisher, Jr.
47. Selected bibliography of North American fresh-water fishery biology, 1941–1946. Prog. Fish-Cult., Vol. 9, pp. 213–230.

is, H. Mabel
34. The physical and chemical oceanography of the Irish Sea. Jour. Cons. Perm. Int. Expl. Mer., Vol. 8, pp. 87–92.

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06. Literatur zur Fischkunde. Bonn, Martin Hager, 140 S.

sel, Max
24. A bibliography of American natural history. Vol. 1, Brooklyn, Premier Publ. Co., 244 pp.
26. A bibliography of American natural history. Vol. 2, Brooklyn, Premier Publ. Co., 741 pp.
29. A bibliography of American natural history. Vol. 3, Brooklyn, Premier Publ. Co., 749 pp.

er, Erna W.
27. Bibliographie der Alters- und Wachstums-Bestimmung bei Fischen. Jour. Cons. Perm. Int. Expl. Mer, Vol. 2, pp. 236–258.
30. Bibliographie der Alters- und Wachstums-Bestimmung bei Fischen. II. Nachträge und Fortsetzung. Jour. Cons. Perm. Int. Expl. Mer, Vol. 5, pp. 88–100.
34. Bibliographie der Alters- und Wachstums-Bestimmung bei Fischen. III. Nachträge und Fortsetzung. Jour. Con. Perm. Int. Expl. Mer, Vol. 9, pp. 377–391.

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941. An annotated bibliography of fishways. Univ. Iowa Studies, Eng. Bull. No. 23, 72 pp.

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951. Schöne Fischbücher. Stuttgart, Lothar Hempe, 108 S.

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946. A bibliography of whales and whaling, selected papers from the Norwegian research work, 1860–1945. Hvalrådets Skrifter, Nr. 30, 32 S.

illips, W. J.
927. Bibliography of New Zealand fishes. New Zealand Mar. Dept., Fish. Bull. No. 1, 68 pp.

bb, James
946. Notable angling literature. London, Herbert Jenkins, Ltd., 229 pp.

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1904. Supplement to a catalogue of the collection of books on angling belonging to Dean Sage. New York, DeVinne, 24 pp.

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1949. A bibliography of lobster culture. Fish and Wildlife Serv., U. S. Dept. Interior, Spec. Sci. Rept. No. 64, 26 pp.

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imada, Bell M.
1951. An annotated bibliography on the biology of Pactfic tunas. Fish and Wildlife Serv., U. S. Dept. Interior, Fish. Bull., (No. 58), Vol. 52, pp. 1–58.

Soler, Pedro Jaime
  1951. A bibliography of the fishes and fisheries of Puerto Rico. Proc. Gulf and Caribbean Fish. Inst., 3rd Ann. Sess., App. No. I, pp. 143–151.

Speirs, J. Murray
  1949. Bibliography of Canadian biological publications for 1946. Ont. Dept. Lands and Forests, Div. Res., Biol. Bull. No. 3, 91 pp.

Speirs, J. Murray, and J. M. Johnston
  1950. Bibliography of Canadian biological publications for 1947. Res. Council Ont., 102 pp.

Speirs, J. Murray, J. M. Johnston, and Ruth Kingsmill
  1950. Bibliography of Canadian biological publications. Res. Council Ont., 126 pp

Steinbeck, John, and Edward F. Ricketts
  1941. Sea of Cortez. A leisurely journal of travel and research with a scientific appendix comprising materials for a source book of the marine animals of the Panamic faunal province. New York, Viking Press, + 598 pp.

Thompson, D'Arcy W.
  1885. A bibliography of Protozoa, sponges, Coelenterata and worms, including also the Polyzoa, Brachipods and Tunicata, for the years 1861–1883. Cambridge Univ. Press, viii + 284 pp.

United States Department of the Interior, Fish and Wildlife Service
  1950. Doctoral dissertations on the management and ecology of fisheries. Spec. Sci. Rept.: Fish. No. 31, 35 pp.

United States Department of the Navy, Bureau of Aeronautics
  1951. Antarctic bibliography. vi + 147 pp.

Walford, Lionel A.
  1932. The California barracuda *Sphyraena argentea.* II. A bibliography of barracudas. Cal. Div. Fish and Game, Fish Bull. No. 37, 122 pp.

Weil, B. H., Poagie E. Murray, George W. Reed, and Robert S. Ingols
  1948. Bibliography on water and sewage analysis. Georgia Inst. Tech., State Eng. Exp. Sta., Spec. Rept. No. 28, 215 pp.

Westwood, T., and T. Satchell
  1883. Bibliotheca piscatoria. London, W. Satchell, xxiv + 397 pp.

Wheeler, Genevieve C.
  1931. A bibliography of the sardines. Cal. Div. Fish and Game, Fish Bull. No. 36, 133 pp.

Wood, Casey A.
  1931. An introduction to the literature of vertebrate zoology based chiefly on the titles in the Blacker Library of Zoology . . . . and other libraries of McGill University. London, Oxford University Press, xix + 643 pp.

General Bibliographies

There are a few bibliographies whose combined information covers the zoological field from the eighteenth to the latter part of the nineteenth century. Because of the great increase in scientific research and publishing after 1880, similar general bibliographies on zoology would be of tremendous size. As a substitute for these long-term bibliographies, smaller ones have been developed which cover periods of only a year and are published annually. These were mentioned previously as bibliographic journals. Information on the general bibliographies follows:

Bibliotheca Historico-Naturalis. Verzeichniss der Bücher über Naturgeschichte welche in Deutschland, Scandinavien, Holland, Frankreich, Italien und Spanien in den Jahren 1700-1846 erschienen

.. Compiled and published by Wilhelm Engelmann in Leipzig, this ‹ of viii + 786 pages has three main divisions: Aides, History of ural Sciences, and Zoology. In the Aides section are included the subsions: Bibliographies, Museums, and Nature Societies; Taxidermy; Microscopy. Under the History of Natural Sciences section are also livisions concerning: Publications of Learned Societies and Miscellan-; Natural History Publications. The Zoology division has references :he following subdivisions: Comparative Anatomy and Physiology; cellaneous Zoological Publications; Books on Particular Animal Classand Prehistoric Animals (and Plants).

ibliotheca Zoologica. Verzeichniss der Schriften über Zoologie lche in den periodischen Werken enthalten und vom Jahre 1846-0 selbständig erschienen sind. This work was compiled by J. Vic-Carus and Wilhelm Engelmann and published by the latter in Leipzig. ume 1 has 950 pages, and Volume 2 has xxiv + pp. 951–2,144. These volumes are somewhat similar to Bibliotheca Historico-Naturalis in ir divisions and subdivisions. Volume 1 contains references on the natural ences in general and on invertebrates, whereas Volume 2 is concerned h vertebrates and paleontology.

ibliotheca Zoologica II. Verzeichniss der Schriften über Zoologie lche in den periodischen Werken enthalten und vom Jahre 1861-30 selbständig erschienen sind. The eight volumes were edited by Taschenberg and published by Engelmann at Leipzig. The general n of this work is patterned after the two preceding works, Bibliotheca storico-Naturalis and Bibliotheca Zoologica.

Volume 1, 1887, pp. xvii + 1–864, contains references to natural sciences general, including literature, aides, history, and travel, and general erences to zoology. Volume 2, 1889, pp. viii + 865–1,730, has referces to the literature concerning the lower invertebrates. Volume 3, 1890, . iv + 1,731–2,760, covers the remainder of the insect literature. Volume 1894, pp. v + 2,761–3,648, deals with bryozoans, brachiopods, mollusks, d the lower chordates. Volume 5, 1899, pp. vi + 3,649–4,708, is conrned with birds and mammals, and Volume 6, 1905, pp vii + 4,709–512, has references to paleozoology. Volume 7, 1910–1921, pp. viii + 513–6,256, is a supplement with corrections, completions, and additions the other six volumes.

Catalogue of Scientific Papers. Compiled by the Royal Society of ndon, this catalogue contains lists by authors of all scientific papers pearing in 1,555 journals between 1800 and 1900. It is extremely useful r referring to the works of known authors.

Volumes 1–6, 1867–1872, cv + 5,743 pp., lists the scientific papers pubhed between 1800 and 1863; Volumes 7–8, 1877–1879, xxxi + 2,357 ., list the papers between 1864 and 1873; Volumes 9–11, 1891–1896, xii + 2,966 pp., concern the period 1874–1883; Volume 12, 1902, xxxii

+ 807 pp., is a supplementary volume for the period 1800–1883; and Volumes 13–19, 1914–1925, cx + 7,038 pp., cover the years 1884 to 1900

INDEXES TO REPORTS ON FISHERIES AND ALLIED SUBJECTS

Some of the organizations dealing with fishery and allied matters have issued indexes to their past publications. These indexes are valuable sources of bibliographic references to fisheries studies. Some of them are listed below:

AMERICAN FISHERIES SOCIETY
1929. Index to transactions of American Fisheries Society, volume I-LVIII, (1872-1928), 99 pp. [Another index for years after 1928 is in preparation.]
CALIFORNIA DIVISION OF FISH AND GAME
1947. Publications of the California Fish and Game Commission. Cal. Fish and Game, Vol. 33, pp. 35–51. [this supersedes Bryant, Harold C., 1921. Publications of the California Fish and Game Commission, 1870–1920. Cal. Fish and Game, Vol. 7, pp. 87–98.]
CARNEGIE INSTITUTE OF WASHINGTON
1948. Catalogue of publications and depositories of the institution. Washington, Carnegie Institution of Washington, vii + 388 pp.
CONSEIL PERMANENT INTERNATIONAL POUR L'EXPLORATION DE LA MER
1939. Index to publications by the International Council for the Exploration of the Sea, 1899–1938. 145 pp.
DANISH BIOLOGICAL STATION
1952. Index to the reports of the Danish Biological Station, Nos. I-LIV (1891-1952). Rep. Dan. Biol. Sta., No. 54, pp. 47–54.
FISHERIES RESEARCH BOARD OF CANADA
1950. List of publications of the Fisheries Research Board of Canada, 1901–1949. Fish. Res. Bd. Can., Bull. No. 87, 96 pp.
FULTON, T. WEMYSS
1905. General index to the scientific reports of the Fishery Board for Scotland, 1883–1904, with a list of the papers contained in them. 23rd Ann. Rept. Fish. Bd. Scot., 1904 (1905), Pt. III, Sci. Inv., Rept. No. IX, pp. 166–250.
INTERNATIONAL HYDROGRAPHIC BUREAU
1935. Index of articles and authors for the first twenty-four numbers, March 1923– November 1935. Hydrographic Rev., 70 pp.
1942. Index of articles and authors for numbers 25 to 36 inclusive issued from May 1936 to November 1941 inclusive (Vol. 13 to Vol. 18 inclusive). Hydrographic Rev., 37 pp.
MACDONALD, ROSE M. E.
1921. An analytical subject bibliography of the publications of the Bureau of Fisheries 1871–1920. Rept. U. S. Comm. Fish. 1920 (1921), App. No. 5, 306 pp.
MARINE BIOLOGICAL ASSOCIATION OF THE UNITED KINGDOM
1913. List of publications recording the results of researches carried out under the auspices of the Marine Biological Association of the United Kingdom in their laboratory at Plymouth or on the North Sea Coast from 1886–1913. Jour. Mar. Biol. Ass., Vol. 10 (N.S.), pp. 143–178.
MICHIGAN DEPARTMENT OF CONSERVATION
1950. Publications of the Institute for Fisheries Research, 1930–1949. 20 pp.
OFFICE SCIENTIFIQUE ET TECHNIQUE DES PECHES MARITIMES
1948. Bibliographie analytique des publications de l'Office Scientifique et Technique des Pêches Maritimes. Notes et Rapports (N.S.), No. 3, 72 pp.
RITCHIE, ALFRED
1940. General index to the reports and papers issued by the Fishery Board for Scotland on the subject of scientific investigation from 1905–1937, inclusive. Fish. Bd. Scot., Sci. Inv., 1939, No. 2, 63 pp.

SONIAN INSTITUTION, UNITED STATES NATIONAL MUSEUM
. A list and index of the publications of the United States Museum (1875–
46). U. S. Nat. Mus. Bull. No. 193, 306 pp.
NGTON ACADEMY OF SCIENCES
. Index to the journal and proceedings of the Washington Academy of Sciences.
+ 268 pp.
R, LEE E.
. Ten year index to the Journal of Wildlife Management. Wildlife Soc., 53 pp.

ACKNOWLEDGMENTS

the following are etxended thanks for suggestions leading to the improvement
report: Deborah L. Harlow of the Marine Biological Laboratories, Woods
Massachusetts; A. C. DeLacy of the School of Fisheries, University of Wash-
, Seattle, Washington; Ralph Hile and W. F. Royce of the Fish and Wildlife
e at Ann Arbor, Michigan, and Honolulu, Hawaii, respectively; and Lawrence
ırphy of the Fishery-Oceanography Library, University of Washington.

U.S. DEPARTMENT OF THE INTERIOR
FISH AND WILDLIFE SERVICE
SEP. NO. 371

May 1954 Washington 25, D.C. Vol. 16, No. 5

OFFSHORE SALMON EXPLORATIONS ADJACENT TO THE ALEUTIAN ISLANDS, JUNE-JULY 1953

By Edward A. Schaefers* and Francis M. Fukuhara**

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SUMMARY

The U. S. Fish and Wildlife Service's exploratory fishing vessel John N. Cobb was assigned in 1953 to salmon-fishing explorations in the offshore waters adjacent to the Aleutian Islands, Alaska. Actual fishing operations were carried on between June 9 and July 28. From June 9 to July 17 the vessel fished on the Pacific Ocean side of the Aleutians, from Unalaska Island to near Agattu Island at distances ranging from 15 to 60 miles offshore. From July 17 to July 28 it fished on the Bering Sea side from Umnak Island to Kiska Island at distances ranging from 3 to 45 miles offshore.

Gill nets, a floating long line, a nonstationary floating trap, and trolling gear were fished; except for one salmon taken on the long line, all were taken by the gill nets. None was taken by the trolling gear or the trap. A total of 1,175 salmon was caught in offshore waters during this exploration.

In the Pacific Ocean fishing, 679 salmon were taken in 17 gill-net sets, and only 1 salmon was taken in 4 long-line sets. This catch consisted of 32 percent red, 3 percent silver, 26 percent pink, and 39 percent chum. Catches ranged from 0 to 18 and averaged 6.4 salmon per 100-fathom shackle. Based on random samples weighed at sea under adverse conditions, the average weights of these salmon were as follows: red 5.1 pounds, silver 5.6 pounds, pink 3.6 pounds, and chum 4.9 pounds.

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* Fishery Methods and Equipment Specialist, Exploratory Fishing and Gear Development Section, Branch of Commercial Fisheries.
** Fishery Research Biologist, Branch of Fishery Biology.
U. S. Fish and Wildlife Service, Seattle, Washington

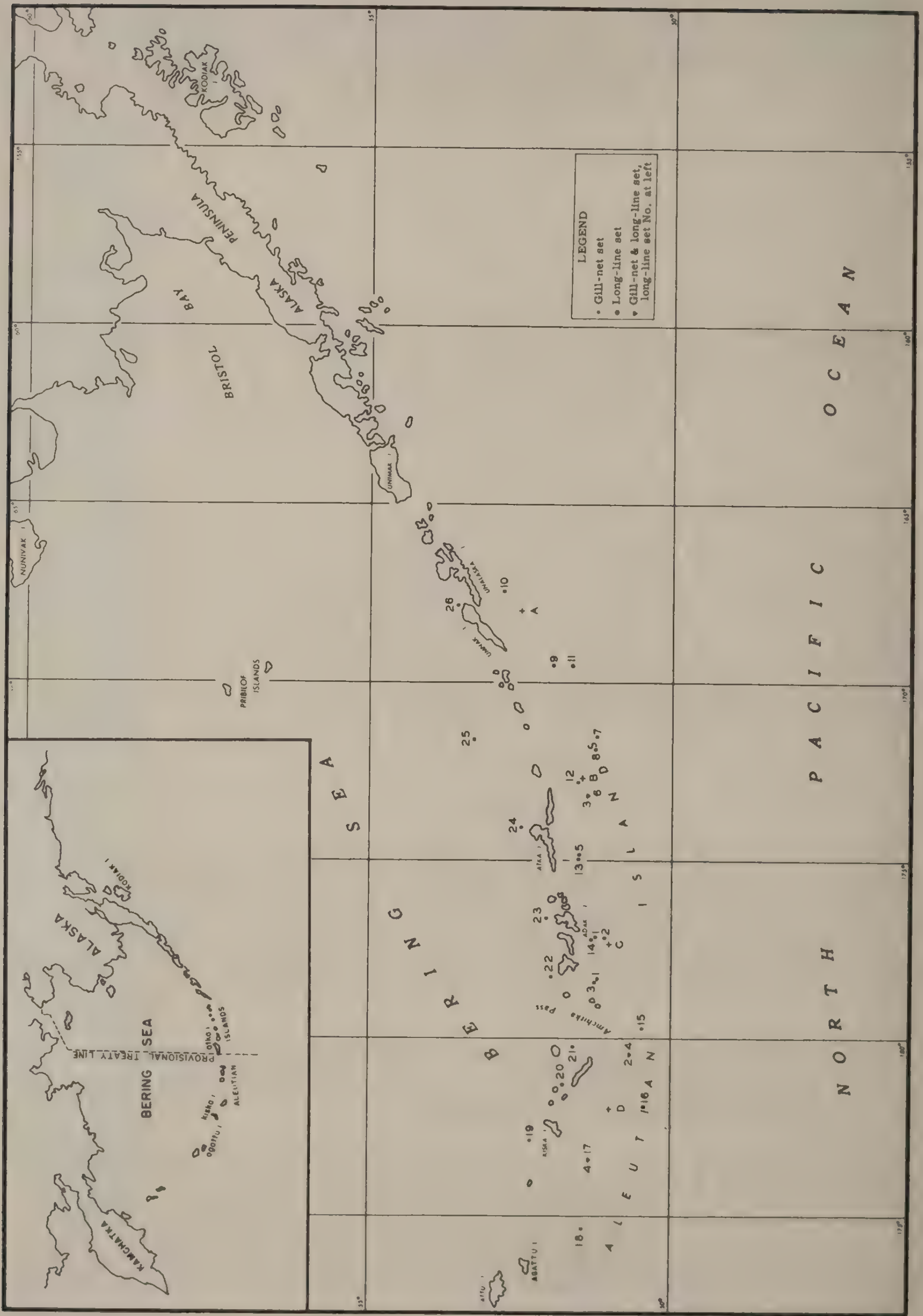
LEGEND
• Gill-net set
• Long-line set
• Gill-net & long-line set, long-line set No. at left
KODIAK I.
ALASKA PENINSULA
BRISTOL BAY
UNIMAK I.
NUNIVAK I.
PRIBILOF ISLANDS
UNALASKA
UMNAK
ATKA
ADAK
Amchitka Pass
KISKA
AGATTU I.
ATTU I.
BERING SEA
NORTH PACIFIC OCEAN
ALEUTIAN ISLANDS
KAMCHATKA
ALASKA
BERING SEA
PROVISIONAL TREATY LINE
ALEUTIAN ISLANDS

Fig. 1 - Aleutian Islands area showing fishing locations.

In the Bering Sea fishing, 495 salmon were taken in 8 gill-net sets. This catch consisted of 2 percent red, 1 percent silver, 3 percent pink, and 94 percent chum. Catches ranged from less than 1 to 28 and averaged 11.2 salmon per 100-fathom shackle. Based on random samples weighed at sea under adverse conditions, the average weights of these salmon were as follows: red 4.1 pounds, silver 6.2 pounds, pink 4.3 pounds, and chum 4.9 pounds.

Although salmon were observed enmeshed from near the top to the bottom of the net, most of them were enmeshed in the upper portion. (The gill nets were 75 meshes deep, $5\frac{1}{4}$-inch mesh, stretched measure.) No evidence was found that the net tended to fish better in certain parts of its length. Red and pink salmon tended to be spaced individually or in pairs at irregular intervals along the length of the net. Chum salmon tended to occur in groups of up to 8 fish along the net. Insufficient silver salmon were caught by the net to warrant conclusions.

The sea conditions caused the gill nets to deteriorate rapidly. Of 19 shackles on board the vessel at the start of the trip, 10 were lost at sea and only $5\frac{1}{2}$ were in serviceable condition at the end of the trip.

Weather conditions seriously curtailed fishing operations during June. During July the weather improved and interruptions to fishing activities were infrequent.

The results of the exploration show that salmon were present over a large area. However, the number of fish taken in individual gill-net sets was small. No attempt was made by the vessel to stay in areas of best fishing, and no conclusions can therefore be drawn as to what the total catch might have been if the vessel had operated only in such areas.

Most of the red, pink, and chum salmon were enmeshed at the nape or the back. Most silver salmon were enmeshed at the head--including gills.

As the net came aboard, the number of dead and live fish was recorded by species. An attempt was made to judge which of the live fish were suitable for tagging. Of the 1,140 fish observed, 875 were dead or nearly dead, and of the live fish, 136 were judged to be taggable and 63 to be possibly taggable and no judgment was made concerning 66 of them. Red salmon appeared to exhibit the most vitality.

Measurements and scale samples were obtained from 1,172 specimens. Fork lengths were obtained from 1,107 salmon. Of these, 179 were red salmon, 706 chum salmon, 197 pink salmon, and 25 silver salmon. The mean length of each species was 564.6 mm., 559.4 mm., 497.9 mm., and 574.7 mm., respectively.

Streams were inspected for salmon in four areas on Unalaska Island and one area on Adak Island. Salmon fry were collected at these localities; however, at the time streams were inspected adult salmon were observed in only one stream. Three male and 2 female chum salmon and 1 male pink salmon were taken in the Chernofski Bay Lagoon stream.

BACKGROUND INFORMATION

The U. S. Fish and Wildlife Service's exploratory fishing vessel John N. Cobb was assigned in 1953 to salmon-fishing explorations in the offshore waters adjacent to the Aleutian Islands, Alaska. The work was part of the preliminary salmon research by the Service in connection with the International Convention for the High Seas Fisheries of the North Pacific Ocean. Actual fishing operations were carried out between June 9 and July 28. The explorations were conducted jointly by personnel and facilities of the Service's Branches of Commercial Fisheries and Fishery Biology. A biologist from the Fisheries Research Institute at the University of Washington also accompanied the vessel.

This report is divided into two parts: Part I pertains to exploratory fishing and Part II to biological aspects of the explorations.

OBJECTIVES

The objectives of the explorations were as follows:

1. to gain as much knowledge as possible regarding the distribution, abundance, life history, and racial composition of North Pacific and Bering Sea salmon in offshore waters;

2. to test and evaluate the effectiveness of various types of gear for catching salmon on the high seas;

3. to determine the most practical and efficient method of catching salmon in the open sea in suitable condition for tagging;

4. to collect as many specimens as possible for detailed biological studies of sex ratios, stomach analyses, length frequencies, and other morphological and physiological characters; and

5. to inspect, as time permitted, accessible streams in the Aleutian Islands for salmon fingerlings and/or adults.

GENERAL PLAN

The general plan was to fish in the approximate area of four predesignated stations on the Pacific side of the Aleutian Chain starting approximately June 1, and after each station had been occupied at two different time intervals, to fish on the Bering Sea side of the Islands. The four stations on the Pacific side were located at intervals between Unalaska Island and Kiska Island, at distances of approximately 40 to 50 miles offshore. Their positions, from east to west, were (A) 52°30' N. 168°00' W., (B) 51°30' N. 172°40' W., (C) 51°00' N. 177°20' W., and (D) 51°00' N. 178°00' E. (fig. 1).

Part I - Exploratory Fishing

DESCRIPTION OF GEAR AND FISHING METHODS

Gill nets, floating long line, a nonstationary floating trap, and trolling gear were fished. Except for one salmon caught on the long line, all were taken by the gill nets. None were taken by the trolling gear or the trap.

GILL NETS: The gill nets (fig. 2) were made up in 100-fathom shackles. The netting was 6-thread linen, $5\frac{1}{4}$-inch mesh (stretched measure), 75 meshes deep. The cork line was cotton rope, 7/16-inch in diameter, 100 fathoms long. The lead line was cotton rope, $\frac{1}{4}$-inch in diameter, 105 fathoms long. Breast lines were 54-thread soft-laid cotton twine. Hanging twine was soft-laid cotton, 40 thread on the cork line, and 32 thread on the lead line. Floats were cedar gill-net floats, $3\frac{1}{2}$ x 6 inches, spaced every fourth hanging. Leads were 2 ounces spaced on 10-inch centers. The net was hung 2 meshes to the hanging on the cork and lead lines. It was hung-in 50 percent on the cork line and 47.5 percent on the lead line. Before the net was hung, the netting and twine were treated with a brownish-green preservative; all lines were tanned and run; and the floats were dipped twice in a water-repellent preservative.

Nineteen shackles of gill net were on board the vessel at the start of the trip. Because of losses and wear, only $5\frac{1}{2}$ shackles of serviceable gear remained at the completion of the trip.

For the first two gill-net sets, 5 shackles were tied together and fished as a string, which measured one-half nautical mile in length. The string was then increased for subsequent sets to 10 shackles, which measured one nautical mile in length. After the 10-shackle string was lost in adverse weather, a new string of 5 shackles was fished. Eight sets with these nets left them in poor condition. As much usable gear as possible was salvaged from the worn gear, which combined with the remaining 4 new shackles provided a string of 5½ shackles. The 5½-shackle string was fished for the remainder of the trip.

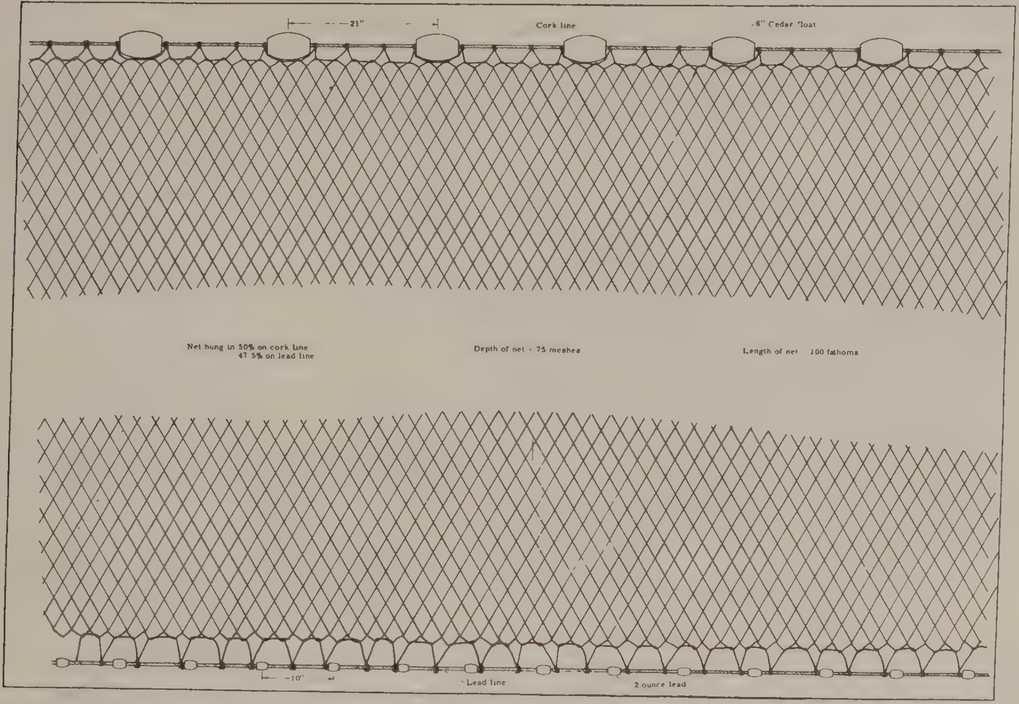
21"
Cork line
6" Cedar float
Net hung in 50% on cork line
47 5% on lead line
Depth of net - 75 meshes
Length of net 100 fathoms
10"
Lead line
2 ounce lead

Fig. 2 - Detailed sketch of a gill-net section.

All sets were made in the evening, usually just before dark. A manila line, 10 fathoms long, with two fabric floats bent on its free end, was attached to one end of the net by means of a bridle. In setting, this end of the net was started out, and as the vessel moved slowly ahead, the rest of the net was allowed to pay out over the stern. A lighted bamboo flagpole and buoy was attached to the other end of the net, and a bridle from the cork line and lead line was attached to a 3-inch circumference manila line. This manila line was rigged with 16-inch inflated fabric floats and 30- and 40-pound lead weights to act as a "bumper" in order to keep the strain off the net (fig. 3). The line was then made fast to the stern of the John N. Cobb. The net was set with the wind, and was held fast to the John N. Cobb at the downwind end. The net was

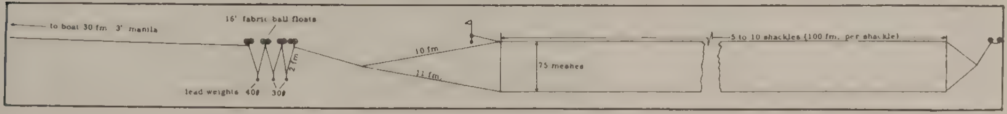
to boat 30 fm 3' manila
16' fabric ball floats
2 fm
lead weights 40# 30#
10 fm
11 fm.
75 meshes
5 to 10 shackles (100 fm. per shackle)

Fig. 3 - Sketch of gill net and "bumper" assembly.

attached to the vessel instead of being allowed to drift free, in order to keep it from being lost in fog and heavy weather. Since the vessel tended to drift at a faster rate than did the net, hanging on to the net prevented, to a great extent, the tendency of the net to "bunch up."

To haul, the vessel proceeded to the windward end of the net. As soon as the free end had been brought aboard, the remainder of the net was hauled from the starboard side amidships while the vessel drifted down the net at a right angle. On several occasions it was hauled from the lee side as the vessel proceeded along the net. This method was used rarely because with any wind too great a strain was placed on the gear. The net came aboard over a gill-net roller on the rail. The roller was 28 inches long and 6½ inches in diameter. The net was hauled by a rubberized sheave 20 inches in diameter, which was powered by a take-off on the main trawling winch. The salmon were removed from the net as it passed over a plywood platform located under the sheave and extending from the roller to the hatch cover (fig. 4). Several times, because of the speed at which the vessel drifted down on the net, it was rapidly piled on deck. The fish were removed later while the net was being overhauled and piled near the stern (fig. 5).

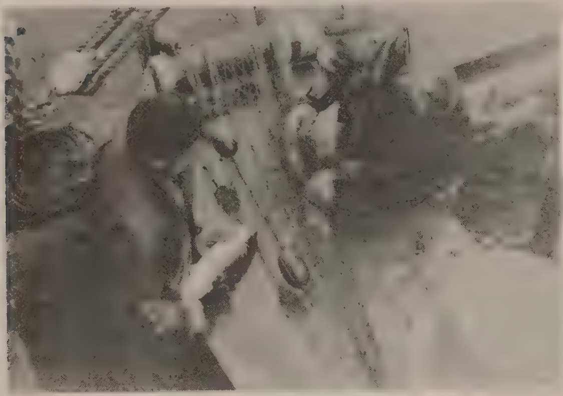

Fig. 4 - Removing salmon from the gill net.

LONG LINE: The floating long line consisted of a main line, gangions (branch lines) with hooks, floats, and a bamboo flagpole float at each end of the main line (fig. 6). The main line was of preformed stainless steel wire 5/64-inch in diameter. It was made of five 200-fathom sections of wire, connected together by bronze trolling swivels, to make an over-all length of 1,000 fathoms. Every 3 fathoms, 2 bronze marking beads were swaged on the main line 4 to 6 inches apart to serve as line stoppers for the gangions. The main line was floated by means of inflated 16-inch diameter fabric floats. These floats were connected with snap-on connectors to the main line by 6-foot drop lines every 30 fathoms along the main line. The gangions, which were made of wire or nylon, had a snap-on connector with a swivel at one end and a hook at the other end. The wire gangions were made of preformed stainless steel, 3/64-inch in diameter and 6 feet in length. The nylon gangions were made of 15- or 20-pound test monofilament and were 5 feet in length. Assorted ringed hooks were affixed to the gangions--size 7/0 to 10/0 on the wire gangions and 4/0 or 5/0 on the nylon gangions.

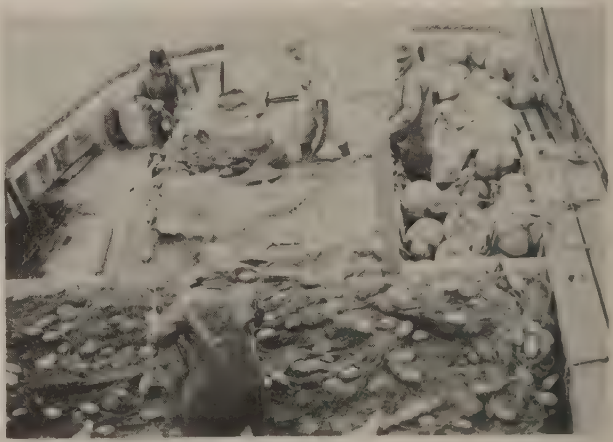

Fig. 5 - Piling the gill net on the stern.

The main line was spooled on a 19.5-inch diameter galvanized reel having a core 10.7 inches in diameter and 3.5 inches in width.

A large bolt was passed through the opening in the core of the reel to serve as an axle. The reel was then set in place near the hatch and braked by hand. A flagpole buoy was attached to the main line and thrown overboard. While the vessel moved slowly ahead, the main line payed out into the water over a halibut chute on the stern. Men stationed on each side of the main line, just forward of the chute, snapped on gangions baited with either herring or pieces of salmon as the line stops passed by. When the main line was completely out, a second flagpole was dropped overboard, and the gear was allowed to drift freely for the desired amount of time.

Before the gear was hauled, the reel was attached to the power take-off on the winch. One end of the main line was brought in over the gill-net roller on the starboard rail and secured to the reel, whereupon hauling was commenced. As the main line was reeled in, the gangions were unsnapped as they reached the roller.

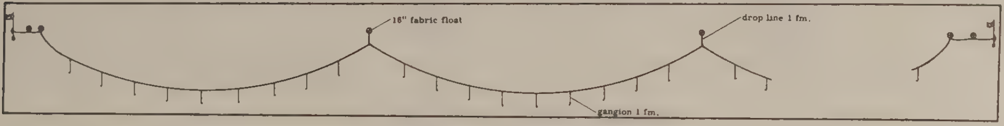

Fig. 6 - Sketch of floating long line.

No difficulty was encountered in hauling, and few snarls were encountered when the gear was set in the manner described. The main line was fairly slack in the water and some of the buoys drifted together as much as 30 percent at times. It is estimated that the gear fished from approximately 2 to 12 fathoms deep.

Three daytime sets of approximately 5-hour duration each were made, with negative results. One silver salmon was taken on a wire gangion and a 7/0 hook during the only nighttime set. In this set, the gill net and long line had been attached together, and the long line was secured to the boat. Since the gill net captured 24 salmon, it is certain that salmon were present in the area the long line was fishing. In this set many gangions became snarled, especially the nylon gangions. It is likely the snarling occurred because in this instance the long line had not been allowed to drift freely.

FLOATING TRAP: The floating trap consisted of a wooden frame, a heart, a spiller, and a lead of netting (fig. 7). Attached to the wooden frame was a framework made of pipe for a small jigger on each side. The heart and the spiller areas were connected by a tunnel of netting. The wooden frame was made of 6-inch by 12-inch spruce timbers and was 16 feet wide and 32 feet long. Each jigger frame was made of 3/4-inch pipe; it extended outward in triangular shape from each side near the heart entrance.

All netting used in the trap was 12-thread cotton netting, 3-inch mesh, stretched measure. The heart and the spiller walls were 30-feet deep, and were lashed to the frames. The heart and the spiller had bottoms cut to the required dimensions established by the frame.

To maintain the rigidity of the walls, lead weights of from 10 to 40 pounds were used. These weights were suspended from manila line that was in turn threaded through seine rings that were attached to breast lines at various places on the trap walls. Lighter weights were used at the jigger and the heart entrances; heavier weights elsewhere.

To keep the tunnel properly set, 2 wooden poles, each 20 feet long, were threaded through seine rings at each side of the spiller entrance. These poles were spread 15 inches apart at the bottom of the tunnel by means of a short spreader stick secured to them horizontally and lashed with seine leads. The poles were spread 15 inches apart at the top by means of lines running from them to the trap frame.

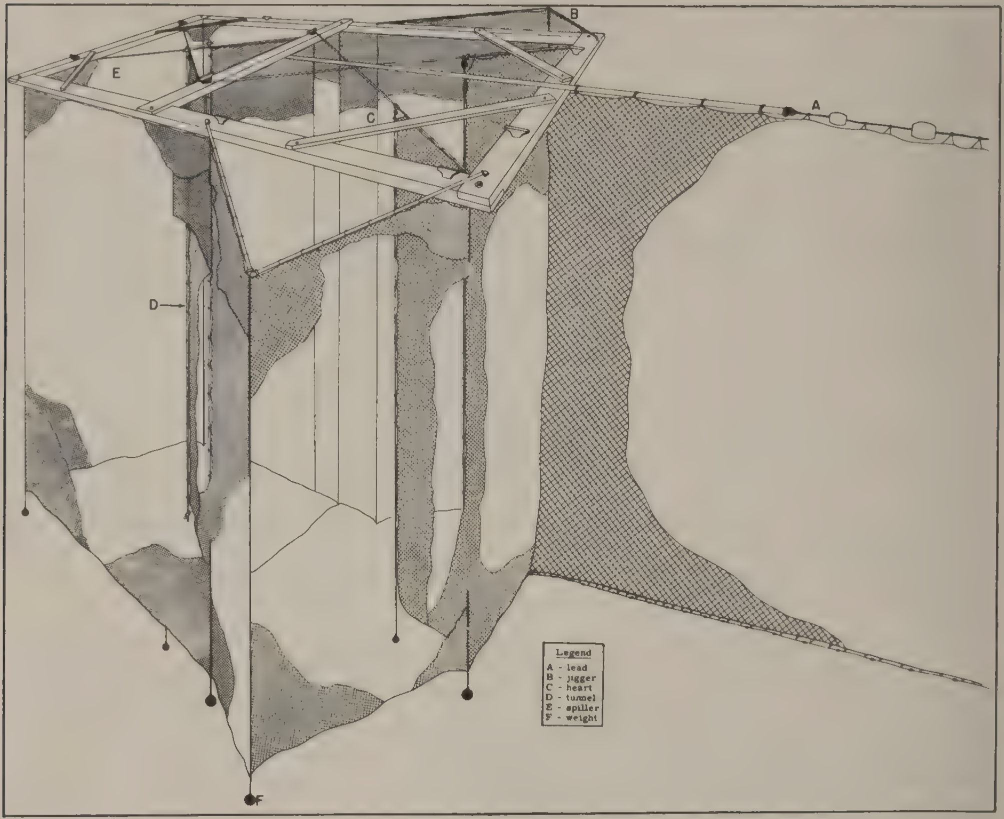

Fig. 7 - Sketch of floating trap.

The lead for the trap was made of $3\frac{1}{2}$-inch mesh (stretched-measure) cotton webbing, 150 meshes deep. Its total length was 500 fathoms, and it was made up in 125-fathom shackles. The cork line was hung-in 25 percent, and the lead line was hung-in 21 percent. The trap lead was hung 3 meshes to each hanging on the cork and lead lines. The cork line was 18-thread manila and the lead line was 15-thread manila. Hanging lines were 24-thread medium cotton-seine twine. Cedar gill-net floats $3\frac{1}{2}$ by 6 inches were spaced 3 per fathom on the cork line as were 4-ounce seine leads on the lead line. The breast lines were 9-thread manila rope. The various lines were tanned and run before being made up into the trap lead. The web of the trap and trap lead were both green in color from the preservative used.

The lower part of one end of the lead was attached to the trap at the bottom of the heart entrance, and the upper part was lashed to a pole that extended 12 feet past the heart-end timber of the trap.

Because of adverse weather conditions, the large fishing area to be explored in limited time, and the large size and complicated nature of the trap, it was set in offshore waters only once and for a short time. The trap frame was completely assembled ashore on a dock, and the web was secured to the frame. The trap was then hoisted aboard the vessel, which proceeded to sea. When the vessel reached the testing location, the trap was hoisted over the side. The lead was passed to men in the motor launch, who made it fast to the trap. As the men were lowering the lead weights and poles, the lead was payed out from the stern of the vessel. There was no wind when the trap was set, and it was necessary to straighten out the free end of the lead with the motor launch. After the trap had been set for 5 hours, a strong wind commenced. This made it necessary to haul the trap, and it was retrieved with considerable difficulty. Two sets were made later in protected waters, neither of which caught salmon. Since the trap was set for an insufficient length of time, the tests of the trap are considered inconclusive.

Fig. 8 - Hoisting the floating trap aboard the John N. Cobb.

TROLLING GEAR: The trolling poles were of fir, 40 feet long, mounted on the bulwarks just aft of the main house. One side of the vessel was equipped with hydraulic gurdies and was rigged with wire trolling gear. The other side was rigged for hand trolling with cotton line. Two main lines were fished from each pole; the main lines connected to tag lines made of $\frac{1}{4}$-inch diameter wire of sufficient length to extend from the poles to the after deck; and tag lines connected to spring shock absorbers which were secured to the poles.

The wire main line was 1/16-inch stainless steel and had paired line stops spaced every five fathoms of its length to permit snap-on attachment of individual leaders. On the outer line a 20-pound and on the inner line a 30-pound "cannon ball" lead was used. Five individual leaders were fished from each main line. Standard leaders consisted of a snap-on connector, a 14-inch trolling rubber, a swivel, a 3- to 4-fathom length of 60-pound cuttyhunk, a swivel, 3 to 4 feet of No. 12 stainless steel wire, and a lure with hook. Artificial lures (assorted types and sizes of spoons and plugs) and bait (whole herring or strips of salmon) were used. Leader variations were also tried; these were 10- to 20-pound test monofilament nylon in lieu of No. 12 wire, and braided nylon without cuttyhunk.

In the case of the hand gear, an inhaul line was connected to a swivel and spreader bar at the end of the tag line. The main line for the hand gear was made up as follows: 60 to 70 feet of No. 96 hard-laid cotton halibut line ran to a spreader bar, a swivel, and a 5-pound trolling lead. Tied to the ring at the bottom of the lead was 4 fathoms of 300-pound-test nylon line, which ran to a spreader bar, a swivel, and a 10-pound trolling lead. In the same manner, 4 fathoms of additional line ran to the final 10-pound lead; however, there was no spreader bar. Leaders were the same as for the wire gear but were without snap-on connectors. The first two were secured to the spreader bars, and the third to the ring at the bottom of the last lead. Three leaders were fished on each main line.

Trolling was carried on at depths ranging from near the surface to more than 200 feet. Occasionally fishing near the surface was tried with rods and light tackle. The time spent trolling was limited by the great amount of time required to run full speed between stations and by unfavorable weather conditions.

Table 1--Gill-Net Catch Data, 1953

Set No.	Date	Position of set		Station	No. hours net soaked	No. 100-fathom shackles	Number of salmon caught				Total Salmon	Wind direction and force 1/	Surface temperature	Incidental catch
							Red	Silver	Pink	Chum				
1	6/9 - 6/10	51°17' N.	177°09' W.	C	11¾	5	42	0	4	14	60	SE-2-S-5	42.6° F.	--
2	6/10 - 6/11	51°03' N.	177°10' W.	C	10	5	25	0	5	9	39	SW-5-E-6	43.0° F.	--
3	6/13 - 6/14	51°17' N.	178°25' W.	C	11	10	41	0	15	21	77	W-3-NW-3	42.5° F.	--
4	6/14 - 6/15	50°41' N.	179°33' E.	D	9¾	10	41	0	12	45	98	WSW-4-WSW-6	42.2° F.	--
5	6/20 - 6/21	51°33' N.	174°52' W.	B	11¾	10	23	0	41	114	178	SE-3-S-3	44.5° F.	--
6	6/21 - 6/22	51°24' N.	173°11' W.	B	10	10	11	0	36	39	86	SSE-3-SE-4	45.0° F.	1 mackerel shark, 1 greenling
7	6/22 -	51°14' N.	171°31' W.	B	Net lost	10	--	--	--	--	--	SE-5-7	44.0° F.	--
8	6/27 - 6/28	51°17' N.	171°47' W.	B	9½	5	0	0	0	0	0	SE-3-2	46.0° F.	--
9	6/28 - 6/29	51°58' N.	169°30' W.	A	9¾	5	2	0	0	1	3	E-2-5	47.5° F.	--
10	7/6 - 7/7	52°48' N.	167°27.5' W.	A	10¼	5	3	1	0	6	10	SW-3-4	52.2° F.	1 handsaw fish escaped
11	7/7 - 7/8	51°39' N.	169°31' W.	A	10	5	1	0	2	1	4	N-2-NW-3	50.0° F.	1 steelhead
12	7/8 - 7/9	51°34' N.	172°47' W.	B	10½	5	2	0	2	0	4	SW-2-NNW-3	48.0° F.	1 mackerel shark, 1 rockfish
13	7/9 - 7/10	51°34' N.	174°59' W.	B	10¼	5	1	0	3	1	5	E-2-3	49.0° F.	1 mackerel shark
14	7/11 - 7/12	51°19' N.	177°13' W.	C	10	5	4	2	3	1	10	NE-3	50.0° F.	1 mackerel shark escaped
15	7/12 - 7/13	50°28' N.	179°44' W.	D	10	5	1	5	33	2	41	N-5-6	46.8° F.	1 steelhead, 1 mackerel shark
16	7/14 - 7/15	50°26' N.	178°06' E.	D	10	5½	1	2	13	1	17	SW-4	46.8° F.	--
17	7/15 - 7/16	51°20' N.	176°36' E.	D	13½	5½	9	6	8	1	24	0-Var.-2	48.5° F.	--
18	7/16 - 7/17	51°27' N.	174°39' E.	D	10	5½	7	6	3	7	23	NW-3-WNW-3	48.2° F.	--
19	7/17 - 7/18	52°19' N.	177°08' E.	-	12¼	5½	2	2	2	54	60	WSW-2	48.7° F.	--
20	7/18 - 7/19	51°49' N.	178°43' E.	-	10½	5½	2	0	4	2	8	SW-3-S-2	41.9° F.	--
21	7/19 - 7/20	51°37' N.	179°47' E.	-	9¾	5½	0	0	0	2	2	S-3-SSE-4	43.0° F.	--
22	7/21 - 7/22	52°00' N.	178°16' W.	-	10¾	5½	0	2	0	77	79	S-5-SW-2	42.3° F.	--
23	7/24 - 7/25	52°06' N.	176°36.5' W.	-	11	5½	3	1	4	148	156	WSW-4	43.0° F.	--
24	7/25 - 7/26	52°29' N.	174°05' W.	-	11½	5½	0	0	2	146	148	W-4-E-3-W-4	48.9° F.	--
25	7/26 - 7/27	53°17' N.	171°34' W.	-	11¼	5½	1	1	4	33	39	W-4-WSW-2	49.9° F.	--
26	7/27 - 7/28	53°33' N.	167°51' W.	-	9	5½	2	0	0	1	3	Var.-1-0	44.5° F.	--

1/Wind force is according to Beaufort scale

Table 2--Long-Line Catch Data, 1953

Set No.	Date	Position		No. hooks	Bait	Time soaked	No. salmon	Wind direction and force 1/	Surface temperature	Incidental catch
1	6/13	51°14' N.	178°20' W.	257	Herring, 184 whole, 30 cut; salmon, 43 pieces	4 hrs. 45 min.	0	SW-4-W-4	42.5° F.	1 Alaska pollock
2	6/14	50°41' N.	179°33' E.	264	Herring, 179 whole, 40 cut; salmon, 45 pieces	5 hrs. 20 min.	0	NW-3-WSW-4	42.3° F.	1 mackerel shark, 2 Alaska pollock
3	6/21	51°24' N.	173°11' W.	265	Herring, 220 whole; salmon, 45 pieces	4 hrs. 55 min.	0	S-3-SSE-3	45.5° F.	---
4	7/15 - 7/16	51 20' N.	176 36' E.	262	Herring, 81 whole, 131 cut; salmon, 50 pieces	11 hrs. 25 min.	1	0-Var.-2	48.5 F.	2 handsaw fish

1/Wind force is according to Beaufort scale.

FISHING RESULTS

Fishing operations were carried on from June 9 to July 17 on the Pacific Ocean side of the Aleutian Chain and from July 17 to July 28 on the Bering Sea side (tables 1 and 2). A total of 1,175 salmon[1] were caught during this exploration.

With only one boat, each area could not be simultaneously sampled, and results varied from area to area and within areas at different time intervals. It is possible that if the four stations could be fished at the same time, results would be different from those obtained by the *John N. Cobb*--both as to total catch and number of each species making up the catch.

PACIFIC OCEAN SIDE OF ALEUTIAN CHAIN: The vessel fished from Unalaska Island to near Agattu Island at distances ranging from 15 to 60 miles offshore.

A total of 679 salmon was taken in 17 gill-net sets,[2] and only 1 salmon was taken in 4 long-line sets. This catch consisted of 32 percent red (*Oncorhynchus nerka*), 3 percent silver (*Oncorhynchus kisutch*), 26 percent pink (*Oncorhynchus gorbuscha*), and 39 percent chum (*Oncorhynchus keta*). Catches varied considerably in the gill-net sets, ranging from 0 to 18 and averaging 6.4 salmon per 100-fathom shackle.

The results of fishing operations in each of the four predesignated fishing stations were as follows:

Station C: Fishing operations in the approximate area of Station C commenced on June 9. Three gill-net sets between this date and the morning of June 14 averaged 8.8 salmon per 100-fathom shackle. The catch consisted of 61 percent red, 14 percent pink, and 25 percent chum. A gill-net set in this area on July 11 averaged 2 salmon per 100-fathom shackle. This catch consisted of 4 red, 2 silver, 3 pink, and 1 chum. Negative trolling results were obtained at this station as well as at all other localities where trolling was carried on during this exploration. A single long-line set on June 13 failed to catch any salmon.

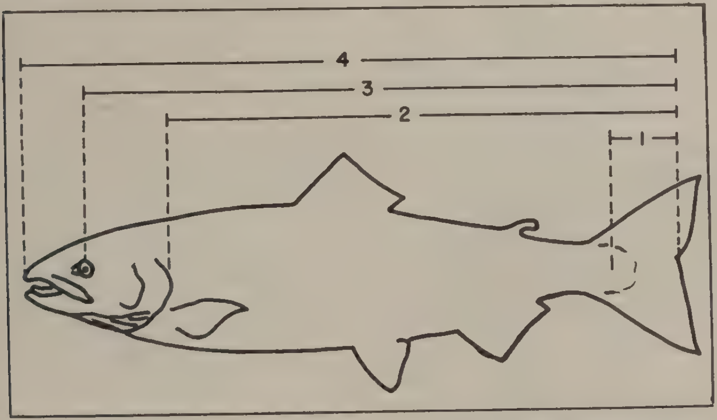

Fig. 9 - Measurements taken of salmon in the catch of the *John N. Cobb*, 1953. Brackets indicate measurements from fork of tail to: (1) posterior margin of hypural plate, (2) leading edge of cleithrum, (3) middle of eye, and (4) tip of snout.

Station D: A gill-net set on the night of June 14 averaged 9.8 salmon per 100-fathom shackle. This catch consisted of 42 percent red, 12 percent pink, and 46 percent chum. Four gill-net sets between July 12 and July 17 averaged 4.9 salmon per 100-fathom shackle. The catch consisted of 17 percent red, 18 percent silver, 54 percent pink, and 11 percent chum. On the night of July 15 weather conditions were ideal and $5\frac{1}{2}$ 100-fathom shackles of gill net were attached to one mile of long line, allowing both types of gear to fish simultaneously. A total of 24 salmon were caught in the gill nets, and 1 salmon was caught on the long line. The latter, a silver, was the only salmon taken on the 4 long-line sets made during this exploration.

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[1] Includes only offshore catches.

[2] Set number 7 is not included as the gear was lost.

Station B: One June 20 and 21, two gill-net sets were made in the general area of this station. An average of 13.2 salmon per 100-fathom shackle were taken in these two sets. The catch consisted of 13 percent red, 29 percent pink, and 58 percent chum. Ten shackles of gill net were lost on the night of June 22 when the net broke loose from the vessel in adverse weather. A set was made on the night of June 27 near where the net was lost, with negative results. This was the only gill-net set of the exploration that failed to catch any salmon. Gill-net sets were again made on July 8 and 9 and averaged only 0.9 fish per 100-fathom shackle. The total catch of these two sets was 3 red, 5 pink, and 1 chum.

Table 3 - Depth at which Salmon Entered the Gill Nets

Species of Salmon	Portion of Net where Salmon were Enmeshed		
	Upper 30 Meshes	Middle 15 Meshes	Lower 30 Meshes
	....	(Number)	....
Red	149	25	35
Silver	19	0	4
Pink	136	13	27
Chum.....	480	73	114
Totals 1/.	784	111	180

1/ Of the total caught by the John N. Cobb, the depths at which 99 salmon entered the gill nets were not observed.

Station A: Gill-net operations in the general area of this station were carried out on June 28 and again on July 6 and 7. The first set caught 2 red and 1 chum. The two sets in July yielded 4 red, 1 silver, 2 pink, and 7 chum.

Weights of random samples taken at sea under adverse conditions that precluded accurate weighing indicated that on the Pacific side red salmon averaged 5.1 pounds, silver 5.6 pounds, pink 3.6 pounds, and chum 4.9 pounds.

BERING SEA SIDE OF ALEUTIAN CHAIN: On the Bering Sea side of the Aleutian Chain, no predesignated fishing stations were selected, and it was decided to begin operations in these waters after Station D had been fished for the second time. Gill-net sets commenced on July 17 off Kiska Island, and seven more sets were made at localities along the Chain as the vessel headed eastward. The final gill-net set was made on July 27 off the eastern end of Umnak Island. These sets were made at distances ranging from 3 to 45 miles offshore. During this time, 495 salmon were taken in 8 gill-net sets. The catch consisted of 2 percent red, 1 percent silver, 3 percent pink, and 94 percent chum. Catches ranged from less than 1 to 28 and averaged 11.2 salmon per 100-fathom shackle.

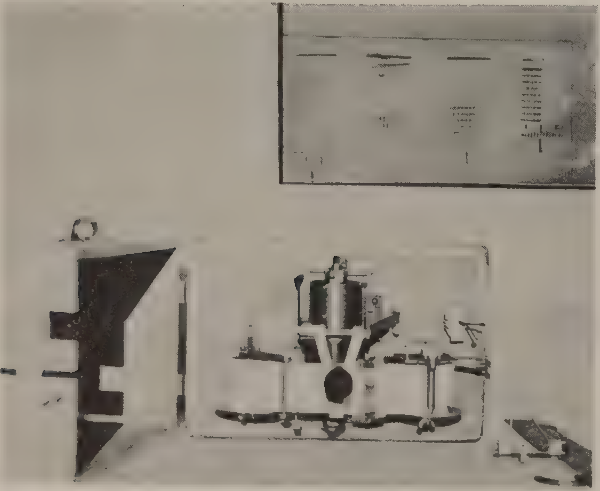


Fig. 10 - Measuring machine used to measure salmon aboard the John N. Cobb. The enlarged inset (upper right) shows the tape on which lengths were recorded.

Each set consisted of 5½ 100-fathom shackles of gill net. The initial set off Kiska Island captured 60 salmon, consisting of 2 red, 2 pink, 2 silver, and 54 chum.

Two sets off Amchitka Island produced a total of only 10 salmon. As operations shifted eastward, fishing improved in the vicinity of Tanaga, Adak, and Atka Islands, and sets in these localities yielded 79, 156, and 148 salmon, respectively. Of the 383 salmon taken in these three sets, 3 were red salmon, 3 silver, 6 pink, and 371 chum. A set north of Amukta Island on July 26 caught 39 salmon, mostly chum. The final gill-net set and the closest to land of any during the exploration caught only 2 red and 1 chum salmon.

Weights of these salmon taken at sea under adverse conditions averaged as follows: red 4.1 pounds, silver 6.2 pounds, pink 4.3 pounds, and chum 4.9 pounds.

The results of the exploration show that salmon are present over a large area. Only one gill-net set failed to take fish. However, the number of fish taken in individual gill-net sets was small. It should be remembered that no attempt was made by the John N. Cobb to stay in areas of best fishing, and no conclusions can be drawn as to what the total catch might have been if the vessel had operated only in such areas. Much more work is required to determine if United States fishing vessels could economically exploit salmon stocks in the offshore waters adjacent to the Aleutian Islands.

RELATED OBSERVATIONS

Various observations were made as the net came aboard: the depth at which the various species entered the net (table 3), the place on the body at which they became enmeshed, their vitality, and their number per shackle. These observations were verified as the individual salmon were removed from the net. Data concerning the place on the body at which salmon became enmeshed and their vitality are presented in Part II.

DEPTH AT WHICH THE VARIOUS SPECIES BECAME ENMESHED: Although salmon were observed enmeshed from near the top to the bottom of the net, most of them were enmeshed in the upper portion. The observations indicated that a net of less depth would be practical, but comparative tests with nets of various depths should be made before definite conclusions are drawn as to the most suitable depth.

Fig. 11 - Measuring salmon aboard the John N. Cobb.

DISTRIBUTION OF THE VARIOUS SPECIES OF SALMON BY SHACKLES: A record was kept of the catch by species for each shackle of the gill net for all sets. No evidence was found that the net tended to fish better in certain parts of its length.

Red and pink salmon tended to be spaced individually or in pairs at irregular intervals along the length of the net. Chum salmon tended to occur in groups of up to 8 fish along the net. Insufficient silver salmon were caught by the net to warrant any conclusions.

SELECTIVITY OF THE GILL NETS: As the gill nets used were of only one mesh size, $5\frac{1}{4}$-inch (stretched measure), the catches by these nets were probably selective. Experimental fishing with nets of various mesh sizes is required to establish the proper sizes to adequately sample the salmon population in these areas.

DETERIORATION OF GILL NETS: The sea conditions during these explorations caused the gill nets to deteriorate rapidly. As the cork line worked in the sea, the hanging line quickly frayed the meshes. After a maximum of 4 sets the top row of

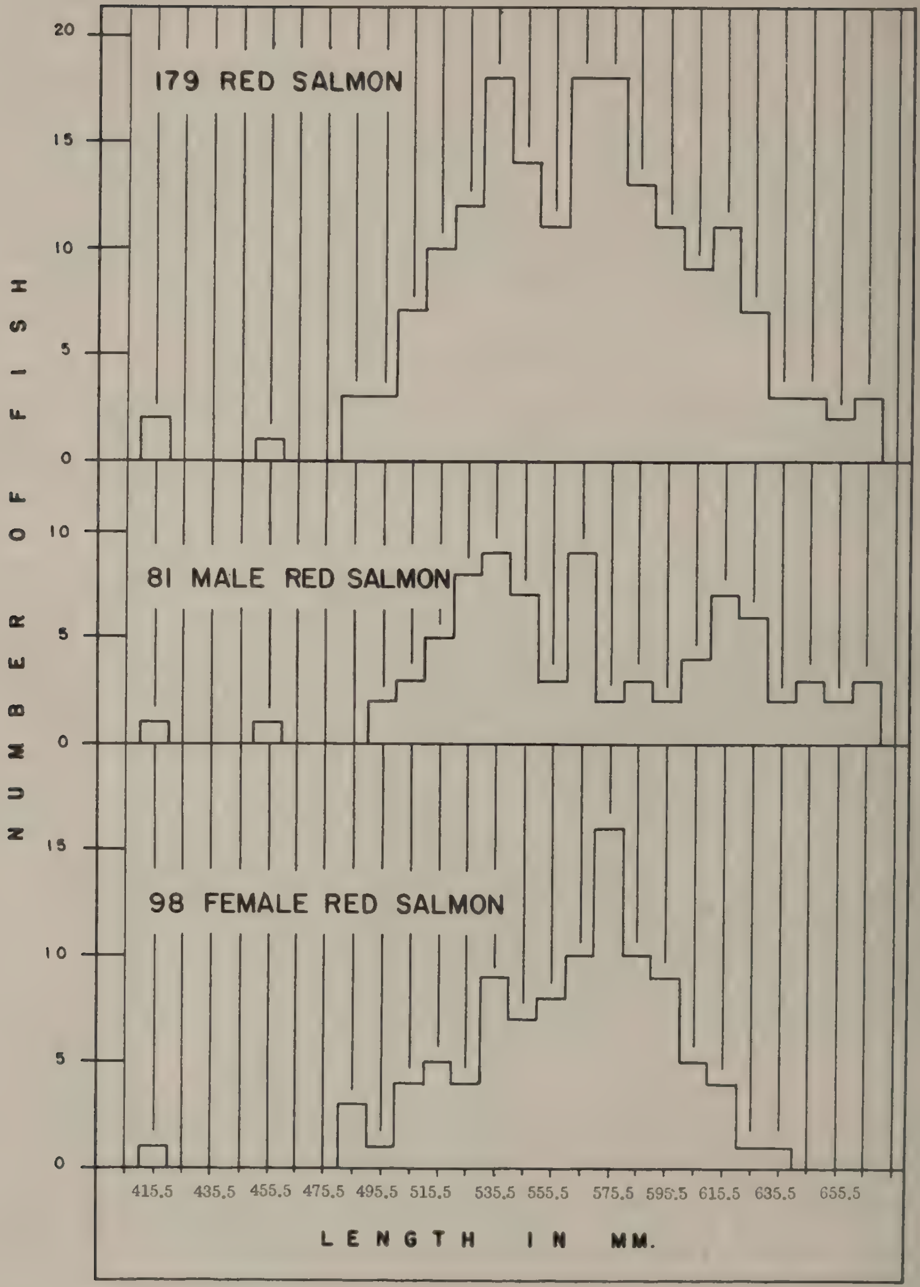


Fig. 12 - Red salmon length frequencies.

meshes had parted at close intervals along the hanging line. This damage was hastened by the strain placed on the nets as they were being hauled. Corks frequently hung up on the roller, and as the vessel rolled in the sea, meshes were ripped loose from the hanging line. To help eliminate this difficulty, the use of a "double" cork line should be tried in the future. This "double" cork line would be formed by running a heavy line along the actual cork line and lashing the two together at frequent intervals. In hauling, the strain would be borne by both lines instead of the cork line alone. It is possible that this method would lessen the tendency of the meshes of the net to rip loose from the hanging line.

Table 4 - Vitality of Various Species of Gill-Net Caught Salmon

Species	Total Catch 1/	Observed 1/	Dead or Nearly Dead	Taggable	Possibly Taggable
	Number	Number	Number	Number	Number
Red	224	217	124	68	25
Silver	28	27	24	1	2
Pink	196	188	158	2/11	2/ 7
Chum	726	708	569	56	2/29
Totals	1174	1140	875	136	63

1/ Errors in observation account for the difference between the total catch and the observed catch figures.

2/ In addition to these, 11 taggable and 7 possibly taggable pink salmon, some or all of 12 other live pink salmon might have been so classified. In addition to these, 56 taggable and 29 possibly taggable chum salmon, 54 other live chum salmon might have been so classified. Owing to difficulties encountered at the time of their capture, observations were not made as to whether these other live pink and chum salmon were taggable. No data could therefore be entered for them here.

Fraying of meshes by action of the sea might be alleviated by removing the corks from the cork line and attaching them to it by drop lines a foot long. The net would then be slightly beneath the surface while fishing and therefore subject to less fraying action.

Table 5 - Place on Body at which Various Species of Salmon Became Enmeshed in Gill Nets

Species	Head Including Gills	Nape	Back	Loose
	. . . .(Number of Fish)			
Red	52	91	60	4
Silver	18	7	2	None noted
Pink	6	41	139	None noted
Chum	191	276	225	None noted
Totals 1/	267	415	426	4

1/ Of the total caught by the *John N. Cobb*, 62 salmon were not observed as to place of enmeshment and are not included in this table.

In an attempt to reduce wear on the net in hauling, a typical Bristol Bay hydraulic gill-net roller was tried. Although the roller operated properly, it proved unsatisfactory; the large size of the *John N. Cobb* prevented adequate control of its angle with the net and its rate of drift.

INCIDENTAL CATCHES: Few fish other than salmon were caught in the gill nets. Several mackerel shark (*Lamna ditropis*), 1 greenling (Hexagrammidae), 2 steelhead trout (*Salmo gairdneri*), and 1 rockfish (*Sebastodes melanops*) were caught. One handsaw fish (*Alepidosaurus aesculapius*) escaped from the net. On the long line a total of 3 Alaska pollock (*Theragra chalcogramma*), 1 mackerel shark, and 2 handsaw fish were taken.

WEATHER: Weather conditions seriously curtailed fishing operations during June. Gale force winds occurred frequently. During July the weather improved and interruptions to fishing activities were infrequent.

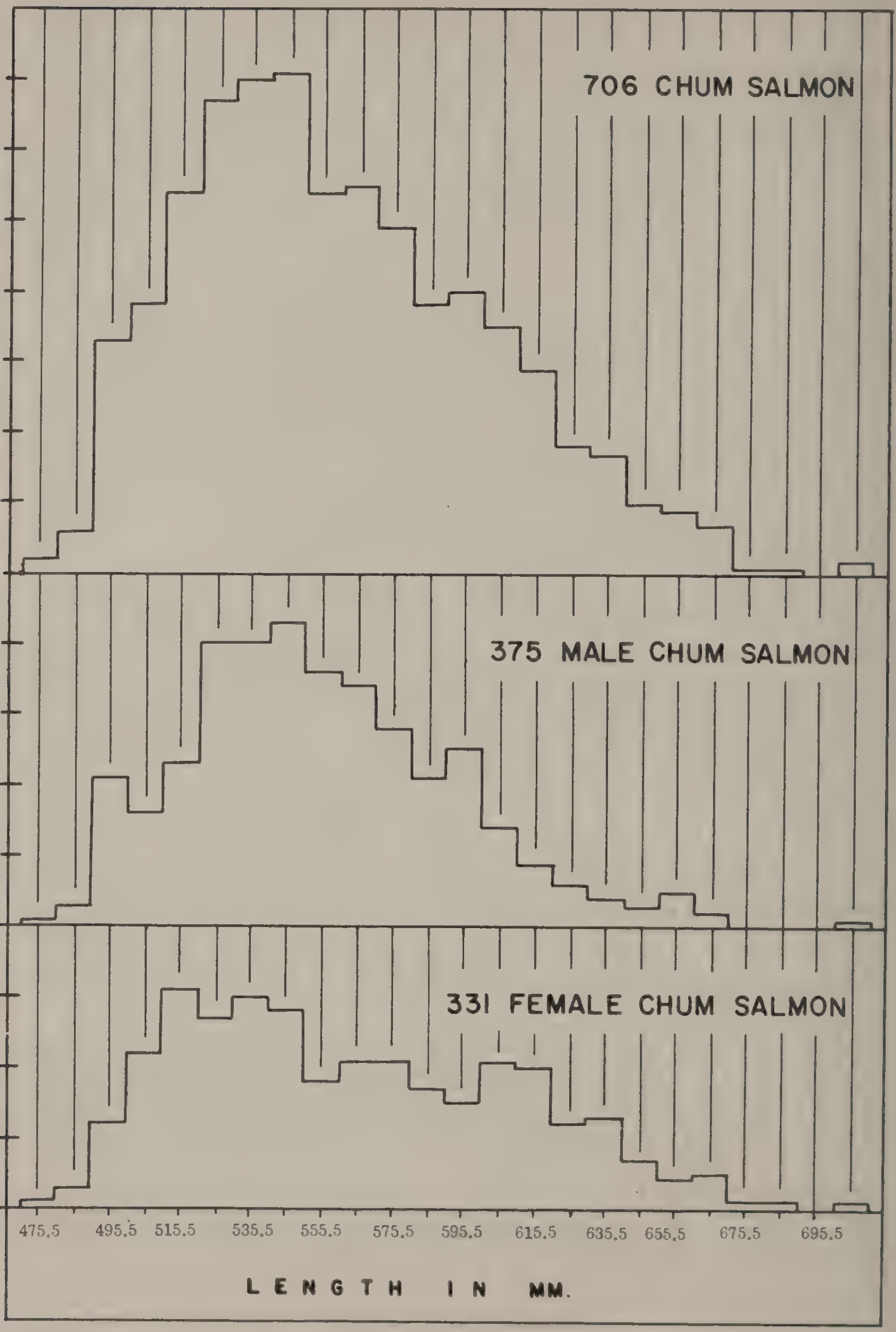


Fig. 13 - Chum salmon length frequencies.

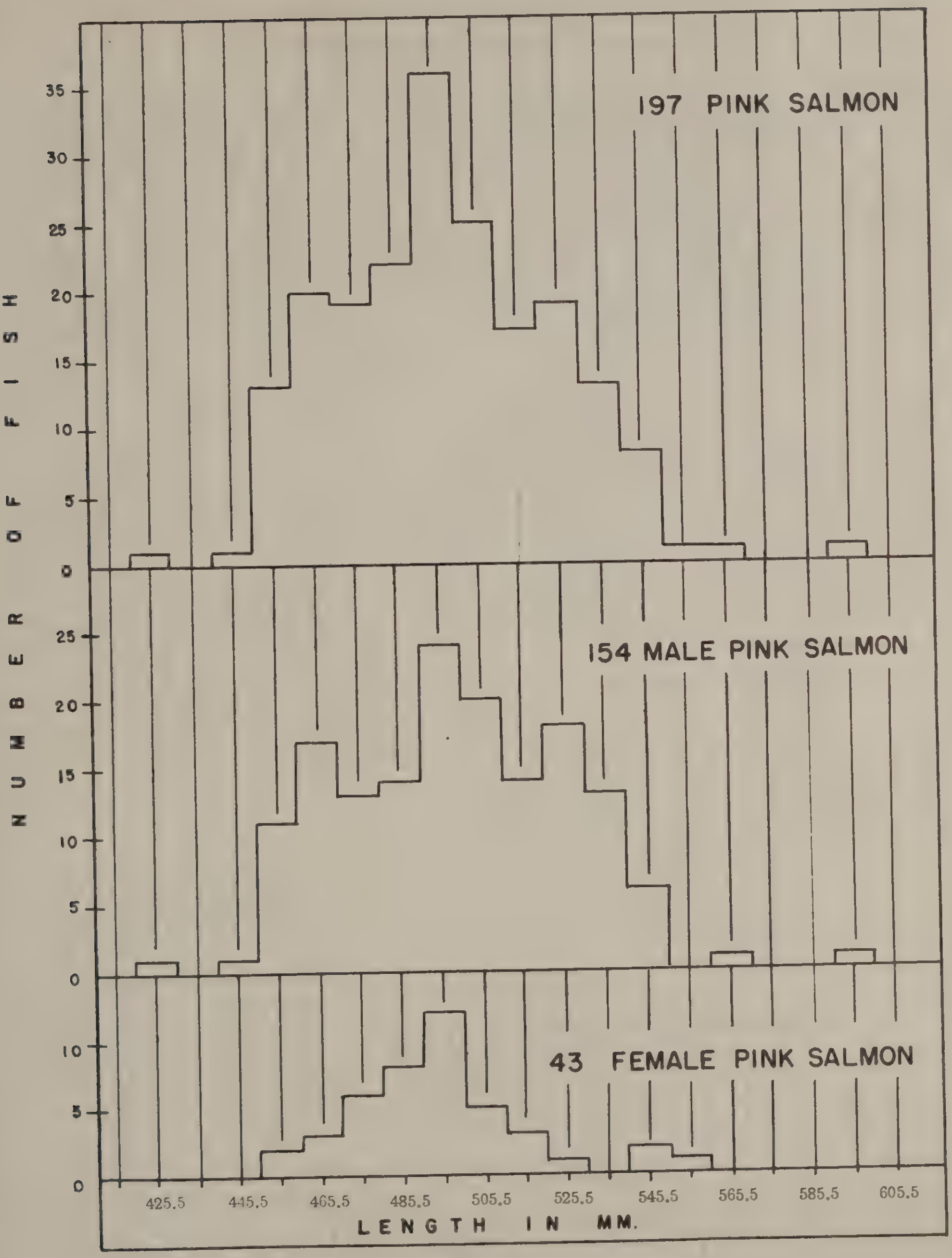


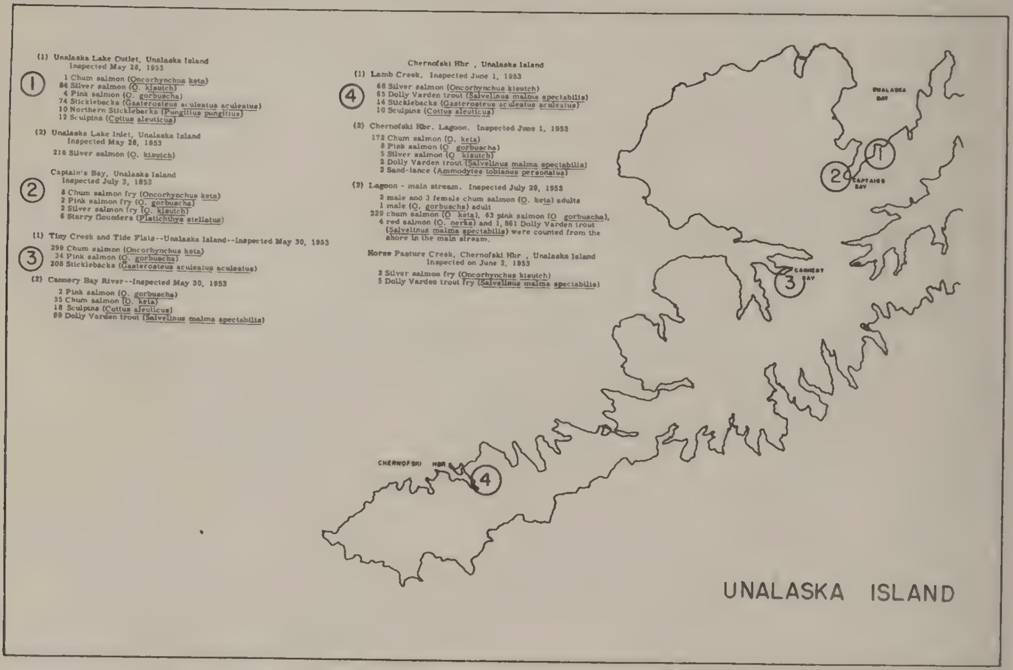
Fig. 14 - Pink salmon length frequencies.

Part II - Biological Observations

COLLECTION OF BIOLOGICAL DATA

OBSERVATIONS DURING GEAR HAULING: Enumeration and identification of species was accomplished by an observer stationed at a vantage point forward of and above the roller over which the gear was retrieved. The vitality of the specimens, the depth of enmeshment, and the position on the body at which the fish became enmeshed were carefully noted.

MEASURING OF SPECIMENS: All measurable specimens (i.e., salmon with heads and tails intact) were measured. In anticipation of subsequent comparisons of length frequencies and proportional measurements with those obtained by organizations at various inshore areas, four measurements were made on each fish. These were from the tail fork to (1) the posterior margin of the hypural plate (marked by an incision at this point), (2) the leading edge of the cleithrum (marked by an incision cut at a right angle to the lateral line), (3) the middle of the eye, and (4) the tip of the snout (fig. 9). Measurements were made on the left side of the fish, i.e., with the fish lying on its right side after coming out of rigor mortis.



①

(1) Unalaska Lake Outlet, Unalaska Island
Inspected May 28, 1953

1 Chum salmon (*Oncorhynchus keta*)
84 Silver salmon (*O. kisutch*)
4 Pink salmon (*O. gorbuscha*)
74 Sticklebacks (*Gasterosteus aculeatus aculeatus*)
10 Northern Sticklebacks (*Pungitius pungitius*)
12 Sculpins (*Cottus aleuticus*)

(2) Unalaska Lake Inlet, Unalaska Island
Inspected May 28, 1953

216 Silver salmon (*O. kisutch*)

②

Captain's Bay, Unalaska Island
Inspected July 3, 1953

8 Chum salmon fry (*Oncorhynchus keta*)
2 Pink salmon fry (*O. gorbuscha*)
2 Silver salmon fry (*O. kisutch*)
6 Starry flounders (*Platichthys stellatus*)

③

(1) Tiny Creek and Tide Flats--Unalaska Island--Inspected May 30, 1953

298 Chum salmon (*Oncorhynchus keta*)
34 Pink salmon (*O. gorbuscha*)
208 Sticklebacks (*Gasterosteus aculeatus aculeatus*)

(2) Cannery Bay River--Inspected May 30, 1953

2 Pink salmon (*O. gorbuscha*)
35 Chum salmon (*O. keta*)
18 Sculpins (*Cottus aleuticus*)
89 Dolly Varden trout (*Salvelinus malma spectabilis*)

④

Chernofski Hbr , Unalaska Island

(1) Lamb Creek. Inspected June 1, 1953

68 Silver salmon (*Oncorhynchus kisutch*)
65 Dolly Varden trout (*Salvelinus malma spectabilis*)
14 Sticklebacks (*Gasterosteus aculeatus aculeatus*)
10 Sculpins (*Cottus aleuticus*)

(2) Chernofski Hbr. Lagoon. Inspected June 1, 1953

172 Chum salmon (*O. keta*)
8 Pink salmon (*O. gorbuscha*)
5 Silver salmon (*O. kisutch*)
2 Dolly Varden trout (*Salvelinus malma spectabilis*)
2 Sand-lance (*Ammodytes tobianus personatus*)

(3) Lagoon - main stream. Inspected July 29, 1953

2 male and 3 female chum salmon (*O. keta*) adults
1 male (*O. gorbuscha*) adult
239 chum salmon (*O. keta*), 63 pink salmon (*O. gorbuscha*), 4 red salmon (*O. nerka*) and 1,861 Dolly Varden trout (*Salvelinus malma spectabilis*) were counted from the shore in the main stream.

Horse Pasture Creek, Chernofski Hbr , Unalaska Island
Inspected on June 2, 1953

2 Silver salmon fry (*Oncorhynchus kisutch*)
5 Dolly Varden trout fry (*Salvelinus malma spectabilis*)

Fig. 15 - Dates, locations, and results of stream inspections on Unalaska Island.

All measurements were made with a measuring machine,[3] lengths being recorded by the machine on a roll of double carbon tape (fig. 10). Scales were obtained from all specimens from an area between the dorsal fin and the lateral line. Occasionally badly descaled specimens were encountered in which scales were taken either from an area between the lateral line and the pelvic fin or from the region between the back and the lateral line behind the dorsal fin. All scales were dry-mounted on glass slides and their surface sculpture was impressed on plastic plates.

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[3] Developed by Dr. W. F. Thompson of the Fisheries Research Institute.

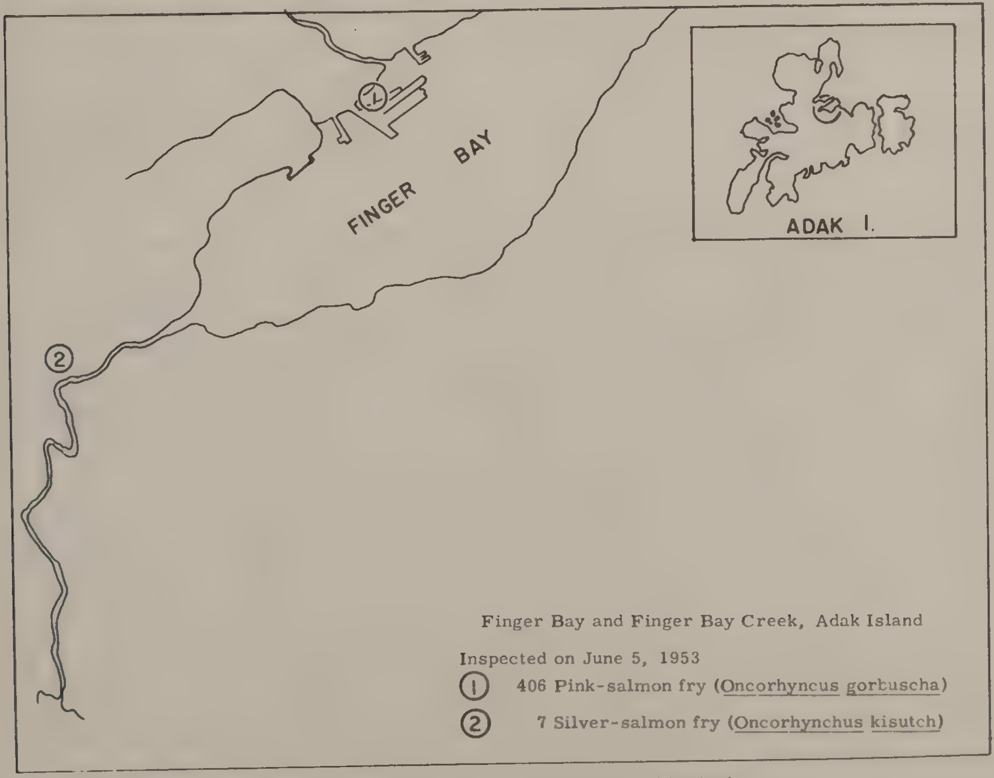
Positive identification of the sex of each fish was made by cutting a small (1- to 2-inch) incision below the lateral line just posterior to the tip of the pectoral fin, and examining the gonads.

After measurements were made and scale samples collected, the salmon were placed in the sharp-freeze compartment and later glazed and stored for shipment to Seattle. Approximately 1,035 specimens were collected. The viscera from most fish not in the collection were preserved in formalin or frozen.

STREAM INSPECTIONS: On occasions when the vessel was "weathered in," several streams on Unalaska and Adak Island were inspected. Whenever salmonoids were seen the area was seined with a 25-foot minnow seine ($\frac{1}{2}$-inch stretched-measure mesh). Juvenile specimens were preserved in formalin. Adult salmon were frozen and placed in the collection.

RESULTS

VITALITY OF VARIOUS SPECIES: As the net was hauled aboard, the number of dead and live fish was recorded by species. An attempt was made to judge which of the live fish were in suitable condition for tagging. This was done before the fish were removed from the gear and represents the judgment of the recorder. These data are summarized in table 4.



Finger Bay and Finger Bay Creek, Adak Island

Inspected on June 5, 1953

① 406 Pink-salmon fry (Oncorhyncus gorbuscha)

② 7 Silver-salmon fry (Oncorhynchus kisutch)

Fig. 16 - Location and results of sampling on Adak Island.

Red salmon appeared to exhibit the most vitality of the various species. Of the 1,140 fish observed, 875 were dead or nearly dead. Of the fish caught in live condition, 136 were judged to be taggable and 63 to be possibly taggable.

ENMESHMENT OF VARIOUS SPECIES: The place on the body at which salmon became enmeshed was noted for as many individuals as possible in order to determine the effect of this factor on the vitality of the salmon. However, variables such as sea conditions and the length of time the salmon were in the net also affect their vitality. Since these variables and their effect could not be evaluated the results are inconclusive. In general, most of the red, pink, and chum salmon were enmeshed at the nape or the back. Most silver salmon were enmeshed at the head (table 5).

MORPHOMETRIC MEASUREMENTS: A total of 1,172 salmon were measured from the catch of the John N. Cobb, of which 219 were red salmon, 725 chum salmon, 201 pink salmon, and 27 silver salmon. However, fork lengths could not be obtained for all specimens due to the absence of or damage to heads and tails of some specimens.

The fork-length frequency distributions of 179 red salmon are shown on the histograms in figure 12. The range in lengths was from 420 mm. to 667 mm. with a mean length of 564.6 mm. Females ranged from 420 mm. to 635 mm. with a mean length of 561 mm. and the males ranged from 420 mm. to 667 mm. with a mean length of 569 mm.

Chum salmon fork-length frequencies are shown in figure 13. Their lengths ranged from 475 mm. to 705 mm. with a mean of 559.4 mm. The females ranged from 475 mm. to 705 mm. and the males ranged from 475 mm. to 705 mm. The mean lengths of the females and males were 564 mm. and 555.4 mm., respectively.

The fork lengths of pink salmon are shown in fig. 14. Pink salmon ranged from 425 mm. to 595 mm. with a mean length of 497.9 mm. The females ranged from 455 mm. to 555 mm., and the males from 425 mm. to 595 mm. The mean lengths were 493.9 mm. and 499 mm., respectively.

The fork length of 25 silver salmon ranged from 544 mm. to 633 mm. The mean length was 574.7 mm.

STREAM INSPECTIONS: The locations of sampling areas on Unalaska Island are shown in figure 15. Sampling areas on Adak Island are shown in figure 16. The results of stream sampling are summarized on the respective figures.

DISEASES OF FISHES OF THE WESTERN NORTH ATLANTIC

I. DISEASES OF THE SEA HERRING
(CLUPEA HARENGUS)

by

CARL SINDERMANN

Maine Department of Sea and Shore Fisheries

and

Department of Biology, Brandeis University

and

AARON ROSENFIELD

Department of Biology, Brandeis University

(This paper is one of several reports resulting from the herring investigation carried on jointly by the U. S. Fish and Wildlife Service, the Department of Sea and Shore Fisheries, the Maine Sardine Packers' Association and the Maine Sardine Industry)

Research Bulletin No. 18

A bulletin of the

DEPARTMENT OF SEA AND SHORE FISHERIES
Vickery-Hill Building
Augusta, Maine

February 1954

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DISEASES OF THE SEA HERRING *(CLUPEA HARENGUS)* FROM THE NORTH ATLANTIC COAST OF THE UNITED STATES

ABSTRACT

The sea herring *(Clupea harengus)* has been found to suffer from several diseases. These infections can be of serious consequence to individual fish and to the herring population as a whole. The outstanding diseases found n the present work are: Fungus Disease, caused by *Ichthyosporidium hoferi;* Ulcer Disease, caused by the myxosporidian *Chloromyxum clupeidae;* Pigment Spot Disease, caused by the trematode *Cryptocotyle lingua;* and Bacterial Tail Rot, caused by a gram-negative, non-spore-forming, pleomorphic rod. External manifestations of certain of these diseases are quite similar. Included in this paper are descriptions of the gross differentiating characteristics of each disease.

INTRODUCTION

Fishes, like humans, are subject to diseases of various kinds and origins—diseases which may produce death, or may render the fish more available to predators. Diseases of marine fishes, with few exceptions, have received comparatively little attention in the past, but with increasing need for proper utilization of marine resources more attention is being paid to factors which may affect the abundance of fishes. One of these factors, probably of greater significance than has been previously recognized, is that of disease.

A systemic fungus disease of the sea herring, caused by *Ichthyosporidium hoferi*, and first noted in scientific literature by Cox in 1916, has been the subject of investigations for a number of years (Daniel, 1933a and 1933b; Fish, 1934; and Scattergood, 1948). Research on this disease is being continued at present at the Boothbay Harbor (Maine) Fisheries Research Station as a joint project of the U. S. Fish and Wildlife Service, the Maine Department of Sea and Shore Fisheries, the Maine Sardine Packers' Association, and the Maine Sardine Industry. During the course of this investigation it has become apparent that herring are subject to a number of diseases, any of which may produce mortalities in wild populations. Several of these diseases cause gross symptoms which are sufficiently alike to be confused upon superficial examination. In each case, external manifestations of disease are such that careful examination will differentiate one infection from another, but in the past many herring have probably been discarded as "diseased" (referring to the fungus disease) when they may actually have been infected with another disease and not with the fungus at all. It was felt that prior to publication of a full report on the fungus infection, a general description of each of the diseases affecting the herring would be important.

The following diseases are described in the present paper: (1) Fungus Disease, caused by *Ichthyosporidium hoferi;* (2) Ulcer Disease, caused by the myxosporidian *Chloromyxum clupeidae;* (3) Pigment Spot Disease, caused by the trematode *Cryptocotyle lingua;* and (4) Bacterial Tail Rot, caused by a gram-negative non-spore-forming pleomorphic rod. It should be kept in mind that other diseases may occur, but the above-mentioned appear to be the principal diseases of the herring.

FUNGUS DISEASE (Ichthyosporidium infection)

ossibly the most serious disease to which the herring is susceptible is that sed by the fungus *Ichthyosporidium hoferi*. This is a systemic parasite ch invades the entire body of the fish. Infection is evident externally by very characteristic " sandpaper effect " (Figure 1) whereby the skin is ed in many tiny papules by proliferation of the fungus in the underlying sculature, giving it a rough, sandpaper-like texture. This effect is espe- ly prominent on the posterior third of the fish. In advanced fungus infec- ns these papular areas enlarge and slough, causing ulcers of varying size h indefinite margins, again most abundant on the posterior third of the ı.

The disease has been reported as reaching epidemic proportions in the ulf of Maine on two occasions: in 1931 (Daniel, 1933a and 1933b; Fish, 34) and in 1947 (Scattergood, 1948). It is of serious economic concern to ose engaged in the catching and processing of herring, since the U. S. Pure od and Drug Administration considers fungus-infected fish unsuitable for erstate shipment. In non-epidemic years (as at the present time) the sease occurs in a small variable percentage of every catch sampled.

The life cycle of this fungus is not completely known at the present time, ut there are indications that the fungus spores are transmitted from fish to h, and that infection takes place through the digestive tract. Spores have en demonstrated consistently in the circulating blood in the present work; is provides a means of internal dissemination of the systemic parasite once vasion has been accomplished. In advanced infections, heart, liver, kidney, nd lateral body muscle tissues are replaced to a large extent by fungus mate- al. Fatal infection has not been experimentally demonstrated in the herring, ue to the fact that this species of fish is too fragile to withstand prolonged xperimental procedures, but has been demonstrated in the killifish *(Fundulus eteroclitus)*, 70 to 110 days after intraperitoneal injection of spore suspension. n preliminary experiments designed to demonstrate the route of infection it as been demonstrated that no interdependence exists between fungus and ematode infection (described below), although simultaneous infections with oth diseases are entirely possible. This fungus disease will be the subject f a later more extensive paper.

ifferentiating features:

The " sandpaper effect ", with subsequent sloughing of skin, particularly n the posterior regions of the fish, are distinguishing external symptoms of ungus infection. Ulceration due to fungus is always accompanied by the " sandpaper effect ", and the margins of the ulcers are indefinite, as opposed o the definite margins and absence of the " sandpaper effect " in ulcer disease described below). Distinction is readily made by examination of the viscera, since the fungus produces gross distortion and enlargement of th heart. White nodules of fungus growth occur on the heart and liver, an among the digestive caeca (Figure 2). Such visceral symptoms are absen in ulcer disease and in pigment spot disease.

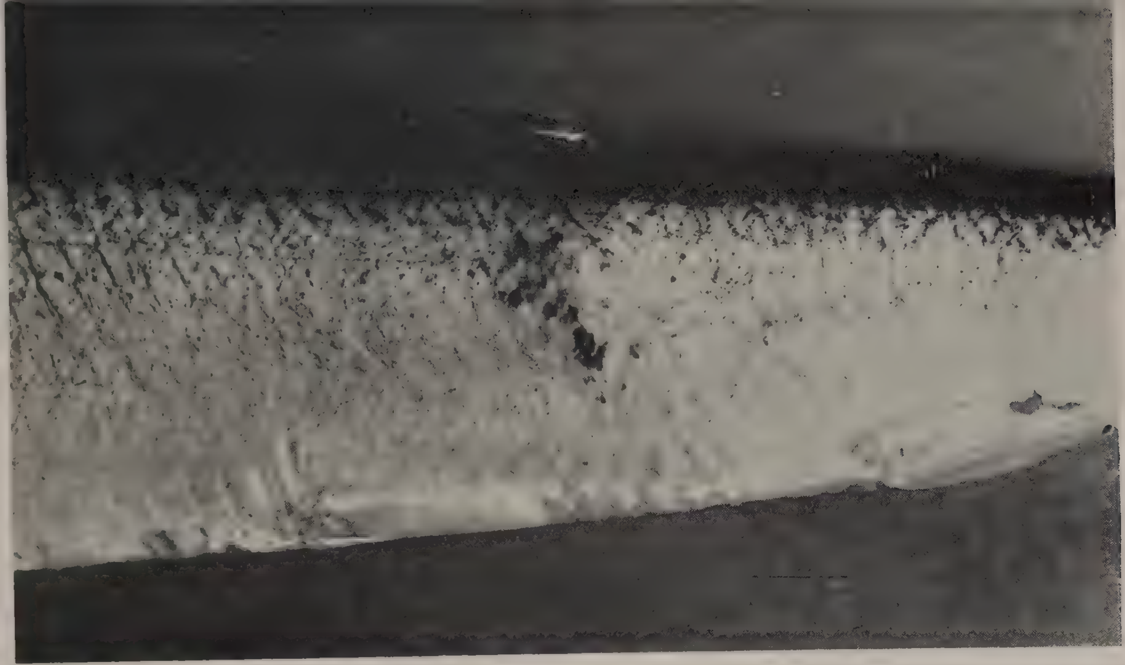

FIGURE 1. External symptoms of Fungus *(Ichthyosporidium)* Disease. Note the extensive and characteristic "sandpaper effect", and in the center of the picture the more advanced ulcerated stage of the infection.

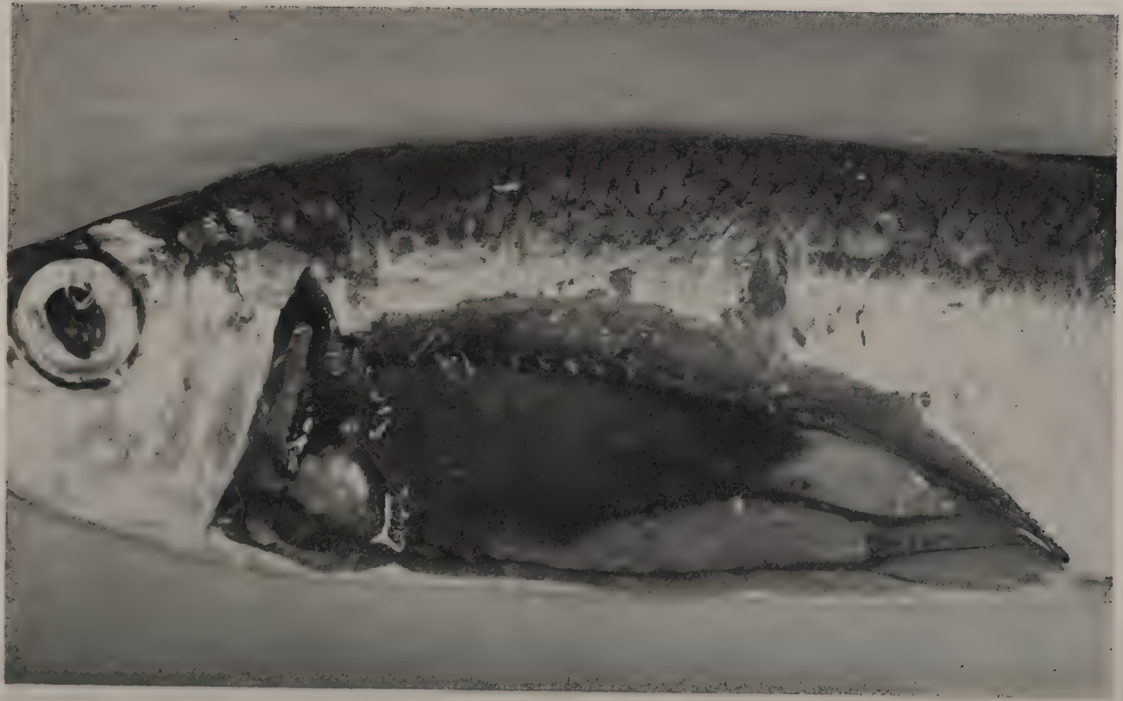

FIGURE 2. Visceral symptoms of advanced Fungus *(Ichthyosporidium)* Disease. Note the extensive and characteristic involvement of the heart, and nodules on the liver and mesenteries.

ULCER DISEASE (Myxosporidian infection)

Frequently herring older than one year are found with one to many dis-ete, usually circular, ulcers, ranging in size up to one centimeter (Figure 3). hese ulcers typically have definite margins and often ooze a white to yellow ecrotic material. Such ulcers are external manifestations of advanced infec-on by a myxosporidian protozoan, *Chloromyxum clupeidae*. This parasite oliferates in the body musculature; eventually the overlying epidermis oughs, producing the characteristic external ulcer. When the skin of herring howing such symptoms is peeled off, many additional areas of protozoan pores and necrosis become apparent. Such areas, commonly called "pus pockets", are often visible as swellings even before the epidermis is removed. amples of herring above the first year class taken in the summer of 1953 ndicate an infection of one to five percent. Open ulcers are frequently con-aminated with bacteria; a gram-negative rod has been isolated from such esions, but this organism appears to be a secondary invader. It appears that he suppurative ulceration characteristic of fish older than one year results rom multiplication of the parasites and secondary bacterial infection.

Herring of the first year group, taken in midsummer at a size of three to ve inches, are often invaded, sometimes very heavily, by this myxosporidian. As opposed to the condition in older fish, external ulcers have not been found n these young fish; the infection is entirely intramuscular, and becomes bvious only when the skin is removed. Invaded areas in the muscles appear s macroscopic, opaque white, usually spindle-shaped masses, which may each a length of three to five millimeters (Figure 4). Such areas are frequently, but not always, oriented parallel to the muscle fibers, and occur with greatest frequency in the antero-dorsal regions of the fish. Samples of first-year fish taken in the summer of 1953 indicate an infection of five to ten percent.

Herring invaded with fungus have been found with concurrent myxo-poridian infections, but interdependence of the two diseases has not been demonstrated.

Differentiating features:

External ulcers are usually few in any single herring, and may be distinguished from the necrotic ulcers which are a manifestation of fungus disease by the complete absence of the "sandpaper effect" characteristic of the fungus infection, and by the recognition of stages in the life cycle of the protozoan in smears taken from the region of ulceration or from "pus pockets" — particularly large numbers of distinctive intramuscular microscopic spores with four polar capsules. In first year fish only spindle-shaped masses of spores are present, while older fish are characterized by "pus pockets" and open ulcers. As opposed to fungus infection, no gross visceral involvement is associated with myxosporidian infection.

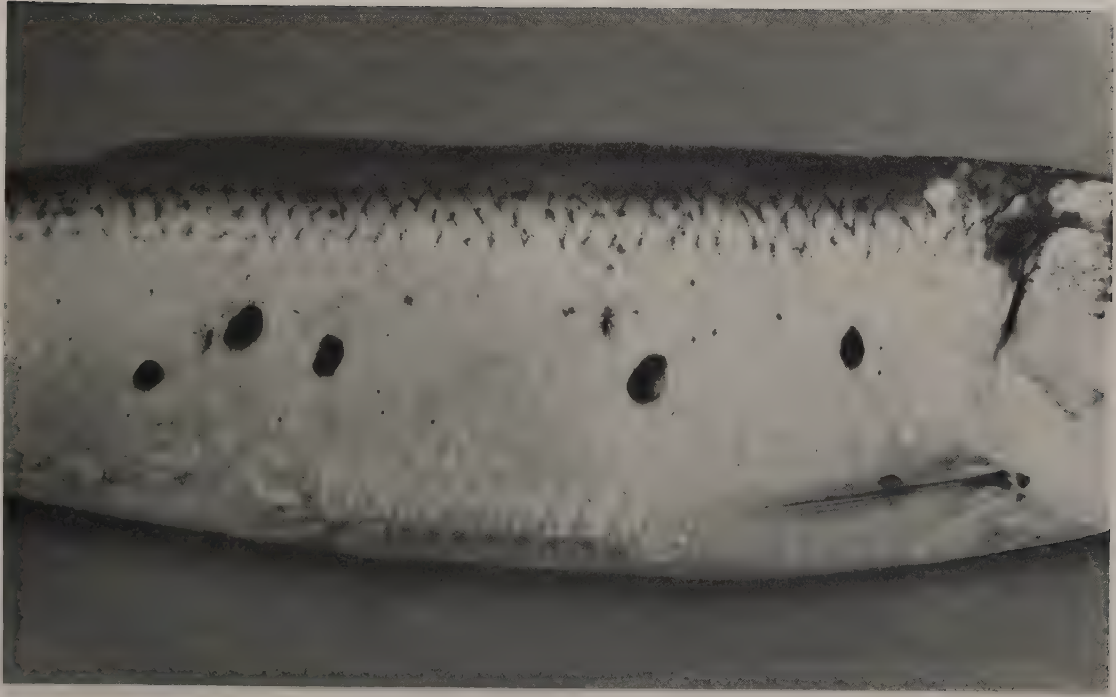

FIGURE 3. External symptoms of Ulcer *(Myxosporidian)* Disease. Note the characteristic oval ulcers with discrete margins.

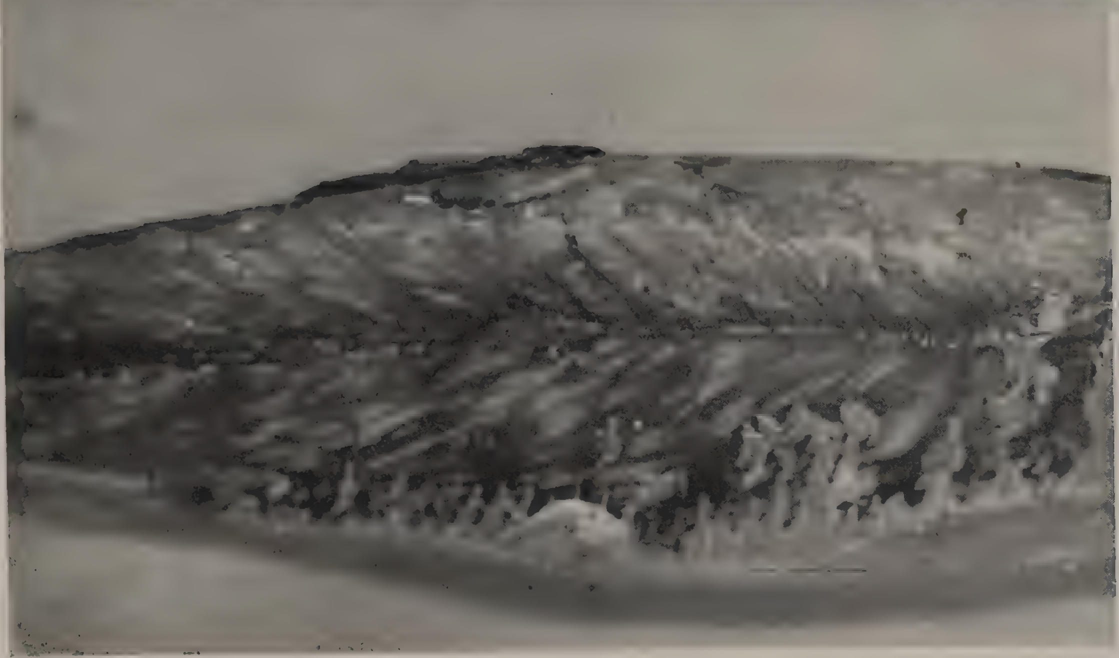

FIGURE 4. Involvement of the musculature of a brit herring heavily infected with *Chloromyxum*. External ulcers are not found in such first-year fish.

PIGMENT SPOT DISEASE (Trematode infestation)

Coastal marine fishes and many species of fresh water fishes are sometimes found peppered with dense black spots, distributed over the entire surface of the body, and frequently the fins as well. Such "pigment spots" or "black spots" result from invasion of the skin of the fish by larval worms (trematodes).

Herring are frequently invaded in this manner by larval stages (cercariae) of the trematode *Cryptocotyle lingua* (Figure 5). Such larval worms usually localize and encyst just beneath the epidermis, but occasionally penetrate deep into the musculature of the fish. Subsequent to this localization, pigment is deposited by the fish host around the encysted worm, producing a macroscopic black spot. The life cycle of the worm responsible for pigment spot of the herring is complex, involving successively the gull or tern, a snail *(Littorina litorea)*, and the herring (Figure 6).

Infection of the herring occurs in inshore waters, in areas where infected snails are abundant. Most herring in their movements into estuaries and coves are exposed to a few of the larval worms liberated by the snails, and evidence a few pigment spots, while a few are literally peppered by them. Heavy infestations can and probably do cause mortalities under natural conditions, although usually the invasion seems light enough to have little or no effect on the fish. It has been demonstrated experimentally in the present work that massive continuous invasion of the herring by such worms will cause death, whereas light infestations, or massive exposure of short duration appear to have little effect. Refinements of these experiments are still in progress.

Differentiating features:

Heavy infestations by larval trematodes may superficially resemble the "sandpaper effect" of fungus disease, but may be differentiated by careful examination. Each worm creates originally a pit or pock-mark in the surface of the skin, rather than a raised papule characteristic of fungus infection; while in advanced worm infestations the metacercariae may often be seen as raised black spots in the center of an area of pigmentation. Also, there are no gross visceral symptoms in worm infestation as there are in fungus infection. Gross differentiating features of fungus, ulcer, and pigment spot diseases are outlined in Table 1.

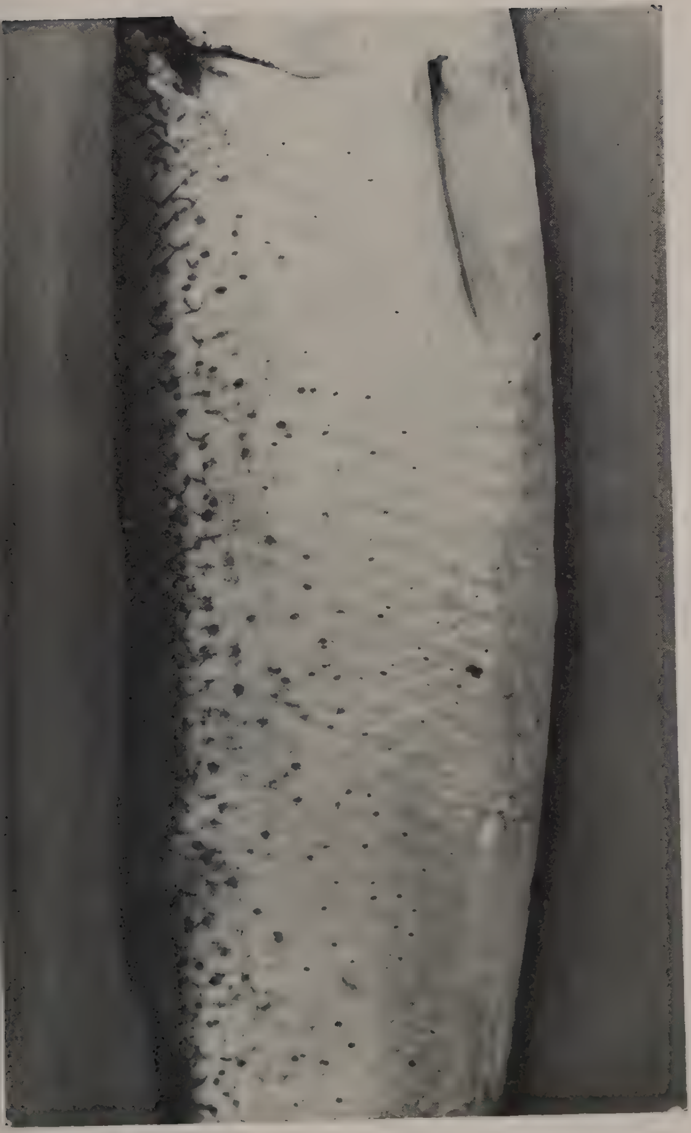

FIGURE 5. Herring with moderate Pigment Spot Disease.

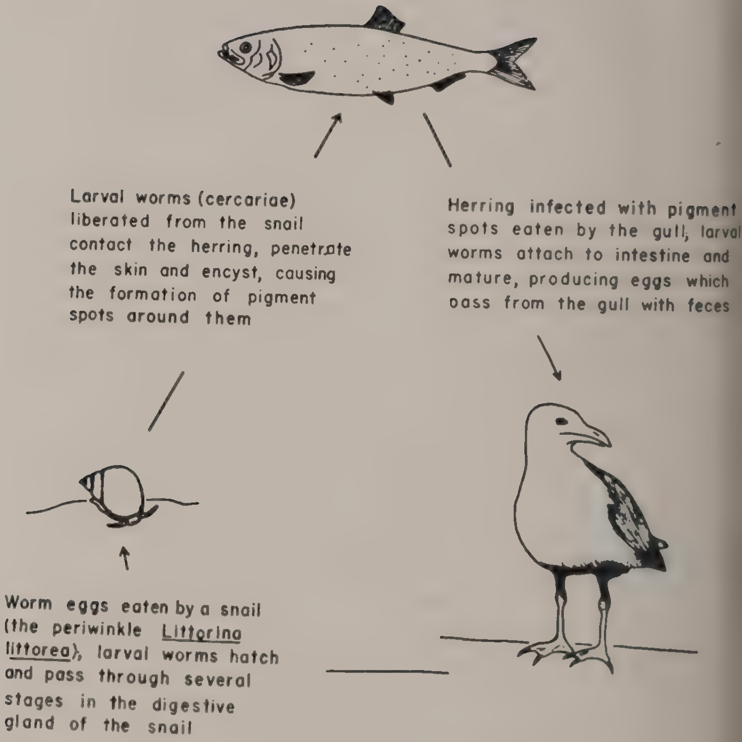
Larval worms (cercariae) liberated from the snail contact the herring, penetrate the skin and encyst, causing the formation of pigment spots around them
Herring infected with pigment spots eaten by the gull, larval worms attach to intestine and mature, producing eggs which pass from the gull with feces
Worm eggs eaten by a snail (the periwinkle Littorina littorea), larval worms hatch and pass through several stages in the digestive gland of the snail

FIGURE 6. General life cycle of the worm *(Cryptocotyle)* which causes Pigment Spot Disease of herring.

TABLE I

GROSS DIFFERENTIATING CHARACTERISTICS OF CERTAIN DISEASES OF THE HERRING

	FUNGUS DISEASE	ULCER DISEASE	PIGMENT SPOT DISEASE
CAUSATIVE ORGANISM	*Ichthyosporidium hoferi* (Fungi, Phycomycete)	*Chloromyxum clupeidae* (Protozoa, Myxosporidia)	*Cryptocotyle lingua* (Platyhelminthes, Trematoda)
SKIN SURFACE	"Sandpaper effect" of raised papules, which slough and coalesce in advanced infection, producing extensive ulceration.	Ulcers usually circular with discrete margins, usually few in any single fish.	Original site of invasion by larval worms marked by pockmark. Pigment deposition and growth of metacercariae produce grossly visible black spots.
BODY MUSCULATURE	Often heavily invaded with spindle-shaped "cysts" of fungus material and connective tissue, especially abundant in the lateral body musculature.	Few to many extensive "pus" pockets visible when skin is stripped from the fish.	Occasional pigmented spots, indicating the localization of larval worms in musculature.
VISCERA	Heart often heavily invaded, in advanced infections appearing as a distorted white mass of fungus material. White nodules on and in heart, liver, mesenteries, spleen, and kidneys.	No gross visceral symptoms.	No gross visceral symptoms.

BACTERIAL TAIL ROT

Fresh water fishes are subject to a number of bacterial infections, some which reach epidemic proportions in hatcheries. Literature on these diseas is abundant, but reports of marine fish diseases of bacterial origin are sparse although many infections probably exist (Oppenheimer 1953). Because the paucity of published information on microbial infections of marine fishe the authors feel justified in including a description of an epidemic bacteria disease which has been encountered repeatedly among herring of differen age groups held in the sea water tanks of the Boothbay Harbor station. Ev dence of this disease has been encountered occasionally in wild population as well.

The course of the infection is rapid, and appears to occur among fish which have lost a number of scales in transfer from nets and weirs. It is charac terized at first by hemorrhagic areas beneath the scales, and a progressive sloughing, first of scales, then of epidermis, revealing large patches of under lying musculature. Before the epidermis sloughs it appears to be raised, cre ating a cottony effect in the affected region of the fish. This effect is easily visible when the fish is in water, but is almost indistinguishable once the fish is removed. The symptoms usually, but not always, appear in the posterior third of the fish, and are accompanied by a characteristic progressive loss of the caudal fin, and in extreme cases, of portions of the caudal peduncle as well (Figure 7). Death normally ensues in one to three days following appearance of external symptoms.

A gram-negative, non-spore-forming pleomorphic rod has been isolated consistently from the regions of sloughing, and from the musculature, blood, and kidneys of fishes which exhibit external symptoms. Other gram-negative rods have also been isolated from open lesions and from running sea water tanks containing infected herring. It remains to be demonstrated whether the causative organism may possibly be a normal member of the marine bacterial flora, which becomes a pathogen of injured fish or of those with lowered resistance. Because of the rapid course of the infection, it is possible that the disease may occur with greater frequency in wild herring populations, but many infected fish may escape observation. It is also interesting to note that this disease is quite similar in many ways to certain bacterial diseases of fresh water fishes (Davis 1946, Snieszko 1952).

In observing the course of this bacterial disease in sea water tanks, indications of other diseases, probably of bacterial origin, have appeared, particularly among brit herring. Some fish exhibit a "popeye" symptom, usually unilateral, in which the eyeball protrudes from its socket, a large clot localizes behind it, and the lens becomes opaque. Other fish are found with extensive intramuscular hemorrhages, but with no external symptoms of infection. These seem to be diseases of herring in captivity, many of which have lost at least a few scales, and have had their diet altered considerably. Such

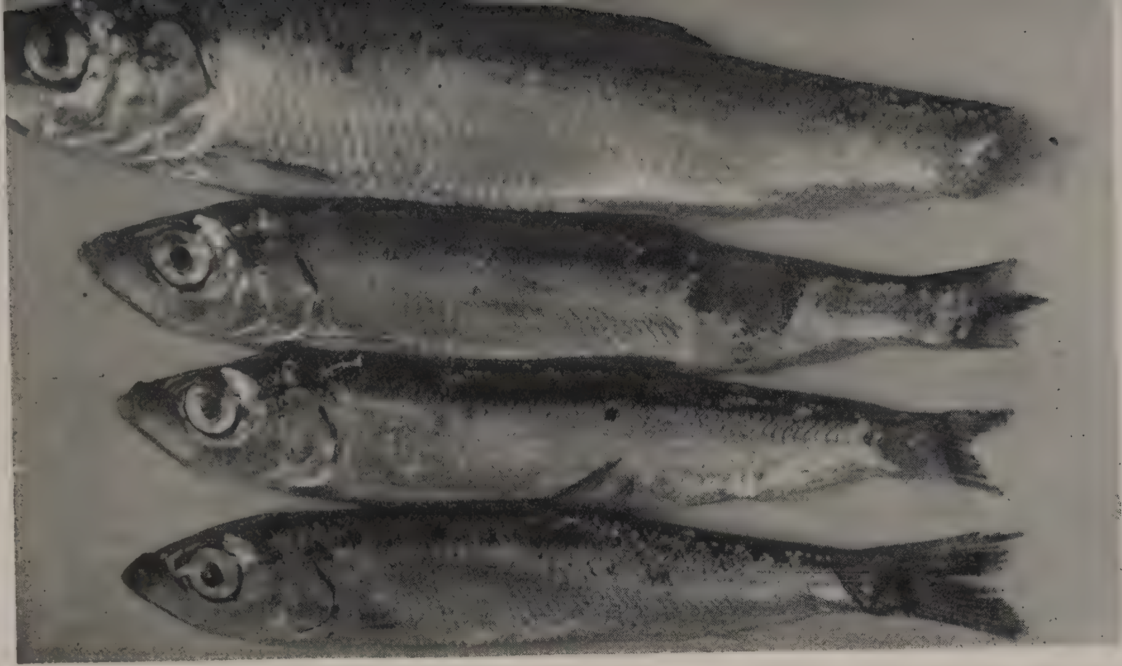

FIGURE 7. Brit herring from the sea water tanks of the Boothbay Harbor Station, suffering from "tail rot" disease.

infections may, however, occur in wild herring populations, and would make an interesting subject for extended research. They might also be studied from the point of view of prophylaxis and treatment, since microbial diseases of marine fishes have not been considered sufficiently in this respect.

DISCUSSION: EFFECT OF DISEASE ON MARINE FISH POPULATIONS

ıe often dramatic effects of disease on fresh water fish populations have reported in the literature, but similar effects often pass unnoticed in marine environment, where many fish may escape observation, where ation quickly removes disabled or weakened fish, and where scavengers kly remove fish which succumb. Many factors are responsible for slow ion of marine fish populations: predators, such as silver hake and pollock ne case of the herring; abnormalities in development, resulting in mal- ations of many kinds; chance injuries, rendering fish susceptible to erial infection; and diseases of many kinds, which affect only a low entage of fishes of any species, and which may affect them at any stage evelopment from the egg to maturity. Similarly, a variety of factors may e mass mortalities among marine fish populations: extreme changes in physical environment — water temperature, oxygen, and salinity particu- (Figure 8); massive growth of other marine organisms. such as the d tide" organisms off the coast of Florida; and epidemic diseases of sev- kinds, in the case of the herring, increase in fungus disease to epidemic portions, as in 1947.

is difficult in the marine environment to assess the entire effect of any gle factor such as disease on the numbers of fish available to man. Con- led laboratory experiments, indicated in the present paper, have demon- ted that mortalities are definitely produced in the herring. Death occurs short space of time in certain diseases. However, except in cases where disease reaches epidemic proportions, this is probably not directly respon- e for a large percentage of losses. Indirect effects of fish diseases probably a more significant role in reducing the numbers of fishes available to n, by weakening the affected fish, slowing them in their escape from dators; or lowering their resistance, thus causing them to succumb to nges in the physical environment, or enabling the establishment of sec- lary invaders. Another indirect effect of disease, of serious economic con- uence, is that infected fish are less desirable or unacceptable for processing food. Several examples of decrease in desirability can be found in marine es: the large ulcers of redfish, caused by a parasitic copepod; the "cod rm", a nematode which localizes in the muscles of the cod; or trematode tacercariae found in flounders — all of which must be removed in prepar- the fish for market. That certain diseases render the infected fish unac- ptable as food is seen in fungus disease of the herring. Canneries will not ept catches of herring with a high percentage of fungus infection, and essive numbers of fungus spores in fish packed as sardines may be cause rejection of that particular pack by Pure Food and Drug inspection.

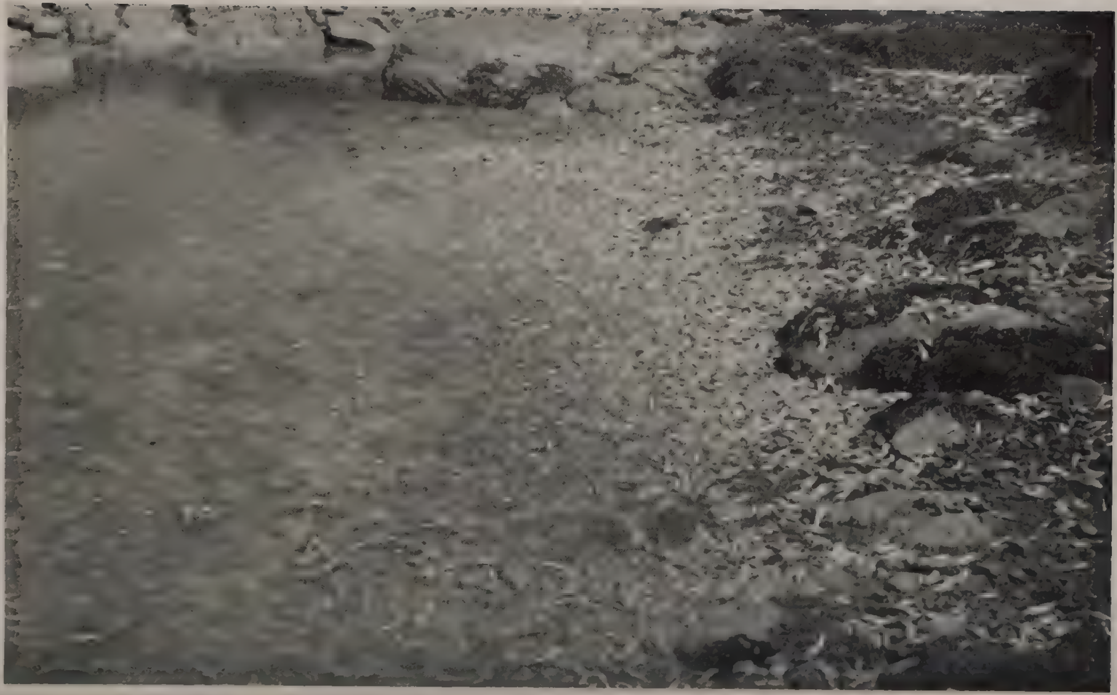

FIGURE 8. Mass mortality of herring, Love's Cove, Southport, Maine, brought about by a combination of predator pressure and physical factors. (Photograph by Gareth Coffin, U. S. Fish and Wildlife Service)

CONCLUSIONS

This paper is concerned only with those organisms of demonstrated genicity to the herring. There are other organisms, internal and ex- , such as monogenetic trematodes on the gills, ectoparasitic copepods e body surface, and digenetic trematodes and nematodes in the intestine, add to the parasitic burden of this fish, but their effect is probably less than the pathogens described here.

It seems clear that the herring is not unusually susceptible to diseases; bly any species of fish, if examined as thoroughly from the point of view sease, would be found subject to a variety of infections (Nigrelli 1946). this work on the diseases of the herring, it would seem profitable to ine the nature and extent of infections of various kinds among other ne fishes used as food, as an aid in assessing the total effect of the factor sease on the numbers of fish available to man.

The similarity of external manifestations of diseases of entirely different ns points out the need for adequate knowledge of diseases of the herring rticular, and of marine fishes in general. In the case of the herring, an ction system has been in operation for a number of years to prevent the ing of fish heavily infected with fungus *(Ichthyosporidium)*. It is of t importance that those responsible for such inspection have full informa- on all diseases to which the herring is subject, to prevent the discarding sh suffering from a disease other than fungus — a disease which may rficially resemble fungus infection in its external or internal manifesta- s.

Concurrent infections with any or all of the diseases described are ible, and have been observed in the herring. Each pathogen, however, ars to be primary, and not a secondary invader.

None of the diseases reported here have been demonstrated as being ogenic to man.

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Symposium

ESEARCH ON FISH DISEASES: A REVIEW OF PROGRESS DURING THE PAST 10 YEARS

eprinted from Volume 83 (1953), Transactions of the American Fisheries Society.
Published 1954. Printed in U.S.A.

Part II

Symposium

RESEARCH ON FISH DISEASES:
A REVIEW OF PROGRESS
DURING THE PAST 10 YEARS

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SYMPOSIUM

RESEARCH ON FISH DISEASES: A REVIEW OF PROGRESS DURING THE PAST 10 YEARS

S. F. Snieszko

Microbiological Laboratory
U. S. Department of Interior, Fish and Wildlife Service
Leetown, West Virginia [1]

INTRODUCTION

Symposia are being included in the programs of the meetings of various rofessional societies at an increasing rate. In some of the symposia, reults of original research are presented for the first time. In others, progress s reviewed in certain fields over a certain period. In this symposium, rogress made during the past decade in the study and treatment of fish liseases, is reviewed; in addition, some unpublished information is preented for the first time. Dr. Louis Wolf, in his letter commenting on this ymposium, emphasized that, "We need to have all this scattered information brought together and thereby made accessible and available." Such eriodic critical reviews are of great value to researchers, the public and dministrators.

I do not know of a better statement of the situation with which the reearch workers are now confronted than the following one made by Dr. Vannevar Bush (1945), director of the Office of Scientific Research and Development during the last world war.

> There is a growing mountain of research. But there is increased evidence that we are being bogged down today as specialization extends. The investigator is staggered by the findings and conclusions of thousands of other workers—conclusions which he cannot find time to grasp, much less to remember, as they appear. Yet specialization becomes increasingly necessary for progress, and the effort of bridge between disciplines is correspondingly superficial.
>
> Professionally our methods of transmitting and reviewing the results of research are generations old and by now are totally inadequate for their purpose. If the aggregate time spent in writing scholarly works and in reading them could be evaluated, the ratio between these amounts of time might well be startling. Those who conscientiously attempt to keep abreast of current thought, even in restricted fields, by close and continuous reading might well shy away from an examination calculated to show how much of the previous month's efforts could be produced on call.
>
> The difficulty seems to be, not so much that we publish unduly in view of the extent and variety of present-day interests, but rather that publication has been extended far beyond our present ability to make real use of the record. The summation of human experience is being expanded at a prodigious rate, and the means we use for threading through the consequent maze to the momentarily important item is the same as was used in the days of square-rigged ships.

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[1] P. O. Kearneysville, West Virginia.

Realizing this pressing need for summary reviews in the field of fishery research, I suggested 2 years ago that in addition to the presentation of research papers, symposia be added as a regular feature of the programs of the meetings of the Society. I also volunteered to organize one on fish diseases for the 1952 meeting. The approval of my suggestion was too late to permit me to prepare such a symposium last year and therefore it is being presented now. So far as I know, this is the first symposium on fish diseases ever held.

If the idea of symposia and review papers appeals to the members of the Society (and I think it will) symposia on various aspects of fishery problems should be included in the program of each year's meeting but they should not replace the usual presentation of research papers. I should also suggest that symposia on the same subject, as this one on fish diseases, be repeated at intervals of about 5 years.

In the selection of the subjects and speakers for this symposium, I was motivated by the desire to have reviewed those subject matters in which either considerable progress has been made, or may be anticipated.

To assist those interested in the literature on the subject, I have selected the following six references on fish diseases which I consider as most comprehensive: Davis (1946) on diseases of trout; Schäperclaus (1941), Lyman (1949), Allison (1950) and Davis (1953) on disease of warm- and cold-water fishes; Wunder (1949) on diseases of warm-water pond fishes; and Dobie *et al.* [in press] on the diseases of minnows.

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ADVANCEMENTS IN PREVENTION AND TREATMENT OF PARASITIC DISEASES OF FISH [1]

LEONARD N. ALLISON

Michigan Department of Conservation
Grayling, Michigan

ABSTRACT

The most recent advancement in control of external organisms causing fish disease is the pond-treatment method. It is an improvement over the hand-dipping method because fish are not killed by handling, fewer men are needed to carry it out, and the pond itself is treated along with the fish. All external parasites are controlled by a treatment with formalin (diluted to 1:4000) for an exposure of 1 hour, except *Ichthyophthirius multifiliis*, parasitic copepods, and species of *Saprolegnia*. *I. multifiliis* can be controlled by holding affected fish in swiftly running water for several weeks or by chemical treatment of the water for the duration of the life cycle of the parasite. Free-swimming larvae of the copepod *Salmincola edwardsii* can be killed by chemical added to the water; because of the parasite's long life cycle, treatment would hardly be feasible at large hatcheries. *Saprolegnia* sp. (fungus) can be killed readily by dipping fish in a 1:15,000 solution of malachite green for 10 to 30 seconds, or by introduction of the chemical into the pond for 45 minutes at a dilution of 1:180,000. Fish eggs can be kept fungus-free by semi-weekly treatments with a 1:200,000 concentration of malachite green.

Comparatively few internal parasites cause mortalities among fish. *Octomitus salmonis* can be controlled by adding 0.2-percent calomel or carbarsone to the food for 4 days. Adult tapeworms of the genus *Proteocephalus* can be purged from fish by feeding for 1 week food containing 1½- to 2-percent kamala. Fish can be protected from the eye fluke (metacercaria of *Diplostomum flexicaudum*) by killing all snails in the pond and preventing entrance of infective cercariae with the supply water.

INTRODUCTION

The control of parasitic diseases of fish is of prime importance if we are to rear fish successfully. The search for more effective methods and drugs to combat fish parasites is, as it is in human medicine, never-ending. The purpose of this paper is to bring together advancements made since about 1940 in the use of new drugs and the methods of application. With one exception, the discussion will be confined to the control of parasites found in fish hatcheries, since control of fish parasites in nature is, with present knowledge, seldom possible.

NEW METHODS OF TREATMENT

The treatment of fish for external parasites is accomplished by hand dipping and pond treatment. In the former method, fish are taken from the trough or pond and dipped, a few at a time, in a solution of the chemical prescribed for the parasite present, and then returned to the trough or pond. This method has many disadvantages. Many man-hours are required to complete the treatment, weak fish are killed because of handling, and, since it is not always possible to sterilize the pond itself, fish are often returned to infested waters.

---

[1] Contribution from the Michigan Institute for Fisheries Research.

The most recent development is that of pond treatment, where chemicals are applied to the entire pond containing infested fish. In this method, fish are not killed by handling, one or two men can do the work, and the pond itself is cleared of parasites along with the fish. In cold-water-fish culture, Kingsbury and Embody (1932) applied chemicals directly to the supply water of ponds, and Fish and Burrows (1939) reported success with recirculation of chemicals through ponds. Although these procedures have definite advantages over the hand-dipping method, they are not generally used. One objection is that disinfectants do not penetrate the sediment in dirt ponds and may be neutralized by the organic matter present.

Fish (1944, 1947) described a method of prolonged treatment in a pond or trough, in which the weight of water is determined and the amount of chemical necessary for the desired dilution is added to the water. Commonly the water level is held below normal with inlet and outlet closed; less of the chemical is required and the pond or trough can be flushed more quickly after treatment. The preparation and administration of this treatment requires little labor and the procedure is well adapted to prophylactic treatments because of its simplicity. Unfortunately, however, it is not possible to employ this method in ponds where inflow and outflow of water cannot be shut off effectively.

Application of the treatment is made by spraying greatly diluted solutions of the chemicals onto the surface of trough or pond. Water sprinkling cans are satisfactory in troughs but are not suitable for large ponds. In Michigan a small power sprayer mounted on wheels has been used to advantage. The outfit consists of a 20-gallon tank, a gasoline motor, and a coil of hose. This unit is economical in that it is also used for other purposes, such as spraying weed killing compounds and certain paints.

CONTROL OF ECTOPARASITES

Most of the parasites that cause mortality among hatchery fish attack fish externally. A list of parasites commonly found follows:

Protozoa:
    Costia necatrix
    Trichodina sp.
    Chilodon cyprini
    Ichthyophthirius multifiliis
    Epistylis sp.
    Scyphidia tholiformis

Trematoda:
    Gyrodactylus spp.
    Dactylogyrus spp.

Copepoda:
    Salmincola edwardsii

Fungi:
    Saprolegnia spp.

/ith the exception of *I. multifiliis, S. edwardsii,* and *Saprolegnia* spp., all these parasites can be eradicated by a 1-hour pond treatment with nalin at a dilution of 1:4,000 (Fish and Burrows, 1939; Fish 1940a, 0b, 1947). Fish (1947) recommended that the quantity of formalin ded for the treatment be diluted about one hundred times and sprayed r the surface of the entire pond to prevent formation of "hot spots" toxic the fish. The formalin should be sprayed into the pond within a period 15 minutes. Since formalin is colorless, a small amount of oxalate crystals malachite green is commonly added to the formalin in Michigan, to serve a "tracer" and show areas of high or low concentrations. L. E. Wolf rivate communication) uses a 1:1,000 dilution of formalin for 20 minutes a trough treatment, but reported that this concentration caused a considable mortality of rainbow trout fingerlings. Fischthal (1949) described *istylus* on brook trout and recommended a 1½- to 2-minute dip in a ution of salt (3 percent) and malachite green (1:15,000) to eradicate e parasite. In Michigan, we have used the formalin pond treatment to ntrol successfully this protozoan.

Because of its more complex life history, *Ichthyophthirius multifiliis* can- t be eradicated by one treatment. Since the stage on the fish is imbedded the flesh and cannot be reached by chemicals, control methods must be med at killing the free-swimming young. The easiest and least expensive ntrol measure is to hold the fish in swiftly running water until all encysted rms have left the fish. The water current carries away the young before ey can infest another fish. When this method is not practical, chemical ntrol must be used.

Fish (1947) recommended daily pond treatment for *Ichthyophthirius* ith formalin (1:5,000 for 1 hour) for 7 to 14 days. Butcher (1947) found at daily pond treatments with 2-percent salt solution for the duration of e full period of the parasitic stage were effective. Wolf (1938) reported e parasitic stage to last 4 to 5 weeks at a temperature of 52° F. At the allarat Fish Hatchery in Victoria, Australia, Butcher (1941, 1947) found at the life cycle of the parasite was from 14 to 16 days at water temperaures of 60° to 62° F. According to these studies, a temperature variation f 8° to 10° F. alters the length of the life cycle by about 3 weeks. Since Volf and Butcher have shown that the length of the parasitic stage depends pon water termperature, the duration of the treatment should be judged ccordingly.

Schäperclaus (1941) recommended a prolonged treatment with quinine o eliminate *Ichthyophthirius*. The chloride, sulfate, or "Chinin-Weil" may e used. He used a dilution of 1:50,000 for the length of time necessary to ffect control (3 to 20 days). He also employed quinine in the same dilution to control *Costia, Chilodonella* and *Cyclochaeta*. He found that these hree were killed in 26, 18, and 6 hours, respectively, at 15° C.

No effective method suitable for large hatcheries has yet been proposed or the eradication of the copepod, *Salmincola edwardsii*, infesting the gills f brook trout. Its tough, chitinous exoskeleton and the habit of burying its head in the flesh of the host protect the adult from chemical treatments.

The free-swimming larvae are vulnerable to chemical control, but since the adult remains on the fish for at least 2 months, chemical control would have to be in effect for that period. Exposure to strong salt solutions, and to formalin in a dilution of 1:6,000 for 1 hour kills free-swimming larvae. Undoubtedly, other effective chemicals could be found. It would hardly be feasible, however, to carry out such a program for 60 days in hatcheries as large as the average state fish hatchery. In states with a number of trout hatcheries, the problem could be solved by rearing brook trout only in those stations free of the parasite, and other species of trout at stations having a contaminated water supply. However, the cost of transporting the fish to streams widely scattered over the state might be prohibitive.

In England, Hindle (1949) effectively controlled *Argulus* on carp in aquaria by an exposure of 2 or 3 days to a 1:10,000,000 dilution of "gammexane" (gamma isomer of hexa-chloro-cyclo-hexane) called lindane in the United States. Since this chemical is insoluble in water it must be dissolved in alcohol before it is mixed with the water. Hindle used a 1-percent alcoholic solution as stock. He pointed out that with few exceptions, this treatment had been applied only to carp and that other species of fish may be less tolerant to the chemical.

The common species of fungus on fish is *Saprolegnia parasitica*. Other species of water mold may appear occasionally, but they need not be listed here since the same control measures apply to all. In the past, solutions of common salt, copper sulphate, potassium permanganate, and possibly others, were used for control, but none gave completely satisfactory results and some were dangerous to the fish. Foster and Woodbury (1936) first employed malachite green as a fungicide. Their experiments, however, involved only a special lot of trout. Although the literature contains warning that only the zinc-free salts should be employed, L. E. Wolf (private communication) reported that he always used the double zinc salt on fish and had uniformly good results. Wolf pointed out that this salt should be used with caution since direct experimental comparisons with the zinc free form have not been made.

O'Donnell (1941) successfully eliminated fungus from 18 species of fish (including brook, brown, and rainbow trout) by dipping them for 10 to 30 seconds in a 1:15,000 solution of malachite green. In Michigan, the chemical is often used in pond treatments, but the methods vary according to the facilities at the different stations. The flush method is used at one location. Here, water in the pond is lowered to a minimum depth, and a strong solution of malachite is introduced at the head and allowed to progress through the pond in a dense cloud. The treatment lasts about a half-hour. At most stations, ponds are treated regularly with a dilution of 1:180,000 for 45 minutes. Where some other external parasite, such as *Gyrodactylus*, is also present, both malachite green and formalin are combined in one treatment.

Saprolegnia attacks both fish and fish eggs. In trout hatcheries, many man-hours are spent picking dead eggs from hatching trays to prevent the development of fungus, unless prophylactic measures are used. From his s of malachite green, formalin, roccal, and hyamine 1622 Burrows 49) concluded that treatment with malachite green in a dilution of 00,000 for an exposure of 1 hour was best for preventing development ungus; cost of the treatment was low and the eggs had a wide tolerance malachite green.

CONTROL OF ENDOPARASITES

Comparatively few internal parasites of fish cause mortalities. Three t warrant discussion here are as follows:

Protozoa:
Octomitus salmonis

Cestoda:
Proteocephalus spp.

Trematoda:
Diplostomum flexicaudum

The protozoan parasite, *Octomitus salmonis,* occurs in the intestines of ut and salmon. Serious mortalities at hatcheries among fingerling trout up 3 or 4 inches long have resulted from infestations by *Octomitus.* Davis 946) reviewed the symptomatology, life history, pathology, and control easures. Only the control measures will be discussed here. Tunison and cCay (1933) successfully controlled *Octomitus* by adding 0.2-percent lomel (mercurous chloride) to the food for several days. Although calomel ay be toxic to fish under certain circumstances, the chemical has been em- oyed commonly in this country for treatment of *Octomitus.* Another emical, carbarsone, was found by Fish and McKernan (1940) and Nelson 941) to be just as effective as calomel for control of *Octomitus,* and not xic to fish. Treatment is made by thoroughly mixing 0.2-percent of car- rsone into the food for 4 consecutive days. We have been using carbar- ne successfully in Michigan for both therapeutic and prophylactic treat- ents. At several hatcheries mortalities from *Octomitus* were experienced nually among brook trout and rainbow trout when the fish were trans- rred from the troughs to raceways. These losses have been eliminated by day treatments each week for 2 weeks before the fish are moved from the oughs, and for 1 week after they are transferred to the raceways.

Davis (1946) suggested that immune races might be developed. The reeding of trout immune to various diseases is a control measure not lly explored. This phase of disease control will be discussed by Dr. L. E. Wolf in another paper in the symposium.

Although tapeworms rarely cause mortalities of fish at hatcheries, the ocking of infested fish is undesirable because of the possibility of intro- ucing the parasite into waters where it does not occur and the possibility f augmenting an established infestation. Adult tapeworms in the intestine f. fish can be removed by the addition of kamala to the diet. McKernan 1940) found 3-inch rainbow trout heavily infested with an undescribed pecies of *Proteocephalus.* He eliminated the infestation in 1 week by add- ng 1½- to 2-percent kamala (by weight) to the food. McKernan suggest- d that the treatment be continued for another week to insure complete elimination of the worms. According to S. F. Snieszko (private communication), this treatment frees brood stock large- and smallmouth bass of the adult *Proteocephalus ambloplitis*. On his suggestion, Mr. Albert Powell, Superintendent, State of Maryland fish hatcheries, treated largemouth bass with kamala which was introduced into the stomach of the fish in capsules. A dose of about 180 to 220 milligrams of kamala per pound of fish for 3 successive days yielded excellent results; great masses of tapeworms were eliminated from the fish.

The larvae (metacercariae) of several species of strigeid trematodes infest the eyes of fish, causing permanent blindness. Palmer (1939) first reported the infestation in hatcheries. Van Haitsma (1930) traced the life history of the eye fluke, *Diplostomum flexicaudum,* and Ferguson and Hayford (1941) described the life history and control of this parasite at Hackettstown, New Jersey. The life history is as follows: the adult of *Diplostomum flexicaudum* lives in the intestine of gulls; eggs pass into water; eggs hatch and miracidia infest snails of the genus *Lymnaea;* cercariae leave the snail and burrow into fish, localizing in the crystalline lens of the eye; gull eats fish; and the adult worm develops in intestines of the bird. Infestations of this worm may cause high mortalities (through starvation) among small fingerling trout, although hatchery trout from 6 to 9 inches long, blinded by the disease, remain healthy when fed a diet that sinks to the bottom of the pond where they can find it (presumably by scent). Fish can be protected from the eye-fluke by elimination of snails from the pond, thus breaking the life cycle of the parasite.

The control of parasites of fish in lakes and streams usually is not feasible. However, an interesting attempt at the control of a fish parasite in nature was initiated in Alberta, Canada, by Miller (1945). In certain lakes in Canada, the plerocercoid of the tapeworm, *Triaenophorus crassus,* infests ciscoes (*Leucichthys* spp.) and whitefish (*Coregonus clupeaformis*) so heavily that the fish cannot be marketed. The parasite, therefore, is of considerable economic importance to the fishing industry. *T. crassus* lives as an adult in the intestines of northern pike (*Esox lucius*). The first intermediate host is the copepod, *Cyclops bicuspidatus;* a variety of salmonoid fishes, particularly the coregonids, can serve as the second intermediate host. Control methods were directed towards breaking the life cycle of the parasite. An unsuccessful attempt was made to kill free-swimming larvae (coracidia) by acidifying a lake (Miller and Watkins, 1945). Partial control was obtained by drastic reduction of the tullibee population (Miller, 1948) in Lesser Slave Lake, Alberta, but there is no assurance that the benefits will be lasting or that the method would be effective in other lakes. In Square Lake, Alberta, Miller (1950) succeeded in reducing the infestation in tullibee by 39 percent when he reduced the population of northern pike. He concluded that the method was not practical because of the ability of northern pike to repopulate depleted areas very rapidly and because of the high cost of the operation. Control of the short-lived, free-swimming tapeworm larvae is now being studied in the laboratory by Miller (1952), who stated that a long period of research evidently will be necessary to conquer the problem.

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THE GENETICS OF FISH DISEASES[1]

MYRON GORDON

Aquarium, New York Zoological Society
New York, New York

ABSTRACT

The clearest evidence for the hereditary determination of diseases in fishes comes from the genetic studies of melanomas. This neoplastic disease in platyfish-swordtail hybrids is initiated, intensified, or inhibited by genetic factors. The development of melanomas depends upon the interaction of a sex-linked, dominant gene obtained from the platyfish and a number of dominant modifying genes obtained from the swordtail. During the past 5 years, evidence has been discovered for the hereditary influence in the development of thyroid tumors in a species of Mexican swordtails. The disease closely resembles the well known thyroid tumors in trout, described about 50 years ago. Kidney tumors of thyroid-cell origin have been detected in several strains of platyfish. In other strains of the same species, living under similar conditions and diets, the kidney tumors have not developed. Several examples are presented of death of fish embryos from hereditary causes. Some skeletal abnormalities of fishes may be traced to injurious genes. The hereditary factors involved in diseases and abnormalities are generally complex and difficult to detect, but the evidence for their existence is undeniable.

INTRODUCTION

The progressive fish-culturist who reviews the 2,596 pages of the United tates Yearbooks of Agriculture for the years 1936 and 1937 will become vidly aware of the tremendous efforts and expenditures that have been ade in the improvement of our domesticated plants and animals by the ractical application of genetic principles. These successes have justified ontinuously greater effort and expenditures to maintain and extend the ains made. It is logical to believe that, given comparable adequate funds or similar research, the fish geneticist could match the successes made by he plant and the non-ichthyological animal geneticist. Fishes have an normously greater reproductive capacity than other domesticated animals, n advantage of immense potential value to the breeder, since it enables the sh geneticist to utilize some of the techniques heretofore found applicable only to plant breeding. Once a pair of fish with desirable characters as been developed the strain may be multiplied on a large scale. We cannot now review the reasons why plant breeding has advanced beyond nimal breeding, nor why animal breeding as applied to fishes has lagged ar behind in obtaining its share of benefits from the application of known rinciples of inheritance.

From the Genetics Laboratory of the New York Zoological Society, at the American Museum f Natural History, New York 24, New York. The work of the Genetics Laboratory is suported by a grant from the National Cancer Institute, National Institutes of Health, U. S. ublic Health Service.

To attain their desired goal, fish-culturists must combine some of the techniques of the modern plant and animal geneticists. The breeding methods for trout improvement initiated by the pioneering work of Embody and Hayford (1925), Hayford and Embody (1930), Davis (1931), Lewis (1944), and by methods and objectives suggested by Keil (1936), Millenbach (1950), and Carbine (1953) must be reappraised for some of them are no longer adequate. The suggestions of Wright (1951, 1952) and Wolf (this symposium) are valuable. Perhaps when someone in the future reviews the progress in fish-cultural practices that will have been made in the next 50 years, as Wood (1953) has done for the last century, he may then be justified in devoting more than a single, short paragraph to the accomplishments of applied fish genetics.

Deleterious Effect of Some Color Genes in the Swordtail

Some look upon color differences between fishes as being rather superficial, and relatively unimportant in terms of the well-being of the animals, but geneticists have found that some of the genes effecting color are associated with a number of major physiological disturbances. In the golden and albino swordtails, *Xiphophorus helleri,* Gordon (1941) demonstrated that color genes not only are expressed in pigmentation effects but they also, in some manner as yet unknown, bring about the death of some fishes during their late embryonic development.

The ancestral olive-gray coloring of the wild swordtail is a mosaic pattern of two major kinds of tiny pigment-carrying cells, the blacks (micromelanophores) and the yellows (xanthophores). The golden swordtail, by a mutational change in its hereditary constitution, lost all but a few of the black cells, but retained its yellow ones. Its eyes were not involved and are just as black as those of the wild fish. The mutational change which transformed the wild swordtail into the golden must have taken place prior to 1921, for in that year, Krasper, a German aquarist, first described the golden sport. Another aquarist, Hildebrand, claimed that the coloring of the wild swordtail was dominant over the golden. Later, Gordon (1938) showed, in a series of genetic tests, that the golden coloration of the swordtail (gene *gg*) was definitely recessive to the gray (gene *GG*) and was typically Mendelian.

The albino swordtail with its light body coloring and pink eyes was discovered about 1934 in aquaria containing the ordinary, black-eyed, olive-gray swordtails. Curiously, the mutant appeared almost simultaneously in American and in European aquaria. Kosswig (1935) was the first to show that albinism in the swordtail is a recessive hereditary trait. His results were confirmed by experiments conducted independently by Gordon (1941).

The albino mutation (gene *aa*) brought about the almost complete elimination of the black pigment normally present in the skin, in the retina of the eyes, and in all other areas of the body. The albino's eyes appear pink in the swordtail not because of any special red pigment, but

ause, as in the pink-eyed albino trout, amphibians, reptiles, birds, and
mmals, the pink color comes from the many fine blood vessels in the
and retina.

When Gordon mated a golden swordtail with an albino, he obtained in
first generation the wild, fully pigmented swordtail. Each of the two
ental color varieties, the golden and albino, brought to its offspring *one*
the essential dominant factors which the other lacked. This example of
ersion to the wild type may be expressed as follows:

Golden × Albino = Wild, olive-gray
gg AA × *GG aa* = *Gg Aa*

The wild-colored offspring (of the first generation from golden and
ino parents) when mated brother to sister, theoretically should have
oduced, out of every 16 born in the second generation: 9 typically wild,
A; 3 golden, *gA*; and 4 albinos, *Ga* or *ga*. When four pairs of F_1 wild-
lored swordtails were mated brother to sister (*Gg Aa* × *Gg Aa*), the re-
lts in the second generation showed fewer albinos and golden than one
ight expect on the basis of the expected 9:3:4 ratio.

Several of the gravid, wild gray F_1 swordtail female parents (*Gg Aa*)
ere killed and dissected. Their embryos were sorted out according to their
enotypes and counted. They were found to be almost exactly in the
tio of 9 gray to 3 yellow to 4 albino. Apparently many of the albino and
lden embryos die just short of their full term. The exact nature of the
use of death has not been discovered. Haskins and Haskins (1948) have
ported almost identical results with the gray, albino, and golden guppies,
ebistes reticulatus.

The Genetics of Dwarfs, or Fishes with Crooked Spines

Anyone who has observed the growth of a thousand or more fishes, be-
veen birth and maturity, has doubtless noticed some physically abnormal
ecimens. The commonest abnormality is some form of a twisted spinal
olumn. In 1934 Gordon found a dwarf platyfish which carried a round
lack spot just in front of its tail. The dwarfing was caused by a defective
pinal column which was coiled between head and tail. The black spot is
herited as a simple Mendelian dominant trait. Breeding experiments
volving this specimen indicated that while the spinal deformity may
ave been of genetic origin, the manner in which the deformity was in-
erited was obscure. In one experiment the hunchback female was mated
o a normal male. The resulting brood of 64 fish included a single specimen
vith a deformed spine, but all showed the black one-spot pattern. In a
econd experiment the hunchback female was mated to another black
latyfish hunchback. From this mating 70 young were born and not a
ingle specimen exhibited any spinal abnormality. In a third experiment
ormal one-spot offspring of deformed parents were mated. In the first
rood of 24 a single specimen was a hunchback.

As opposed to these indefinitive results, Aida (1930) has described genetic experiments with the Japanese medaka, *Oryzias latipes,* in which a crooked spine, which he called "wavy" was inherited. A second type of spinal deformity which he called "fused" also exhibited a Mendelian pattern of inheritance. However, in Aida's experiments the pattern of inheritance was not quite typical, for when abnormal specimens were mated, the members of the next generation showed a few normal specimens. If "wavy" and "fused" were typically recessive Mendelian traits, no normal individuals should appear when similar abnormal recessives are mated. Inheritance of spinal deformities, among guppies, in typical Mendelian ratios has also been described by Kirpichnikov (1935), Goodrich, *et al.* (1942), and by Rosenthal and Rosenthal (1950).

The clear-cut results obtained in the genetic study of twisted spines in the guppy are not matched in the medaka or in the platyfish. This difference indicates that these characters in some species are difficult to study genetically, especially when environmental conditions may have a pronounced effect. Skeletal characteristics of fishes are easily affected by environmental conditions prevailing during early embryonic development, as has been shown by Stockard (1907, 1921), Hinrichs (1925), Gabriel (1944), and Foster, *et al.* (1949). Therefore, in any genetic study involving skeletal characteristics of fishes the environmental conditions, particularly temperature, should be rigidly controlled.

THE INTERACTION OF GENES AND MODIFIERS

A gene, even though it be dominant, may not have any immediate visible expression of its own. A gene of this nature was detected by Gordon (1938) through its effect when in the presence of a secondary hereditary factor. The following example, taken from Gordon (1946a), shows that the interaction of the two genes produces a special effect. The comet platyfish is characterized by one black line along the upper margin and another black line on the lower margin of the caudal fin. The comet pattern may be referred to the comet gene (*Co*) which behaves as a simple Mendelian dominant factor with reference to the absence (co) of that pattern. This may be expressed as follows:

Comet P_1 Non-comet
Coco × *coco*
Comet F_1 Comet
Coco × *Coco*
3 Comet F_2 1 Non-comet
1 *CoCo,* 2 *Coco,* 1 *coco*

Now if the comet platyfish, *CoCo,* is mated to a swordtail which does not have the comet pattern, *coco,* their F_1 hybrids develop an entirely new pattern, known as the wagtail. The wagtail pattern is strikingly different from the comet because all the fins, the caudal, dorsal, anal, pectorals, and pelvics, as well as the tip of the snout and some parts of the operculum become black. Like the pattern of the Siamese cat, all the extremities of the wagtail are darkly pigmented.

When 2 F_1 platyfish-swordtail wagtail hybrids are mated, brother to ter, the following types and their ratios appear in the second generation: wagtails; 3 comets; 4 no pattern.

These results were explained by Gordon on the basis of two dominant nes, one of which is readily expressed (the comet gene *Co* of the platy-h) and the other a modifying gene, *E*, (an *extensor* of the effect of *Co*) rried by the swordtail. The *E* gene has no visible effect by itself, even ough it is a dominant. It can be detected only in the presence of the gene. The genetic method of presenting the matings and the data are follows:

Comet platyfish P_1 Swordtail
CoCo ee × *coco EE*
F_1 Wagtail hybrids
Coco Ee
Wagtail hybrid F_1 Wagtail hybrid
Coco Ee × *Coco Ee*
F_2

Phenotypes:	Appearance
9 *Co E*	9 Wagtails
3 *Co e*	3 Comets
3 *co E* 1 *co e*	4 No pattern

In the development of the wagtail pattern the blackening of parts of ie body never reaches a pathological stage. This is because only small lack pigment cells (micromelanophores) are involved. Micromelanophores great numbers appear, also, over the entire bodies of the melanistic hases of the molly, *Mollienesia*, and the mosquitofish, *Gambusia*, but the enetics of these two species has not been studied sufficiently.

THE GENETICS OF ATYPICAL PIGMENT-CELL GROWTH

In the study of the inheritance of macromelanophore patterns (patterns roduced by large black pigment cells) no abnormalities were noticed mong the offspring when matings were made between members of the ame strain. When, however, a spotted platyfish of one species was mated o a member of another species, their interspecific hybrids showed some bnormalities in the growth of their large pigment cells. Only the spotted atterns involving the macromelanophores produced abnormalities in species hybrids; the micromelanophore patterns remain normal in development in the same hybrid population.

Multiple Factors in the Abnormal Growth of Macromelanophores.—As n aid in visualizing the genetic process involved in the production of melanotic neoplasms in hybrids between the platyfish and swordtail, Kosswig (1931) and Gordon (1937) employed the concept of the multiple-factor hypothesis.

The essential hereditary factor contributed to the melanotic hybrid by its platyfish parent is the sex-linked, dominant factor *Sp*, for macromelanophores. The swordtail parent transmits to its abnormally pigmented hybrid offspring two dominant genes which interact with and modify the normal expression of the *Sp* factor of the platyfish. Since these genes have no visible expression in the swordtail parent, they are referred to simply as *A* and *B*. The following genetic formulae may represent the normal parents involved:

Swordtail × Platyfish (spotted)
spsp AA BB × *SpSp aa bb*

The first generation hybrids are *Spsp Aa Bb*. This genic composition indicates that the platyfish macromelanophore gene, *Sp*, is now associated with two dominant macromelanophore-growth-intensifying factors *A* and *B*. The *Sp A B* hybrids are highly melanotic and this condition generally leads to the development of melanomas. Further studies on the genetics of melanomas in platyfish-swordtail hybrids were reported by Gordon (1950a, 1951).

Genetics of Red-Black Pigmented Tumors.—Tumors in fishes involving the red pigment cells, xanthoerythrophores, are rare. Rarer still is the phenomenon of the invasion and replacement of one kind of tumor by another, pigmented or not. Gordon (1950a) described the genetics of a mixedpigmentcell tumor involving red and black pigment cells, an erythromelanoma in platyfish-swordtail hybrids. Later Nigrelli, Jakowska, and Gordon (1951) demonstrated histologically and cytologically that two kinds of pigmentcell tumors were involved, first, a red tumor, a xanthoerythrophoroma of the head region and, second, a black tumor, a melanoma of the tail region. When joined, the two pigmentcell tumors produced an erythromelanoma.

The genetic history of the erythromelanomas which developed in a significant proportion of a single brood of platyfish-swordtail hybrids was traced to a mating between an exceptionally colored male platyfish and an albino swordtail female. The male platyfish had an unusual combination of sex-linked color genes: *Rt* for ruby-throated and *Sp* for spot-sided pattern were linked on the same chromosome. In this arrangement they were carried in the same gamete. If they were not linked, no erythromelanomas were produced in the hybrids. This situation may be illustrated as follows:

A. Linkage of *Rt* and *Sp* on same sex chromosome
Ruby-throated, spotted platyfish × Albino swordtail

$$\frac{Rt\ Sp}{rt\ sp} \times \frac{rt\ sp}{rt\ sp}$$

F$_1$ Hybrids

1. 50 percent $\frac{Rt\ Sp}{rt\ sp}$, these may develop erythromelanomas.
2. 50 percent $\frac{rt\ sp}{rt\ sp}$, these are normal.

No Linkage of *Rt* and *Sp*

Ruby-throated, spotted platyfish × Albino swordtail

$$\frac{Rt\ sp}{rt\ Sp} \times \frac{rt\ sp}{rt\ sp}$$

F$_1$ Hybrids

1. 50 percent $\frac{Rt\ sp}{rt\ sp}$, ruby-throated hybrids
2. 50 percent $\frac{rt\ Sp}{rt\ sp}$, spotted hybrids, may develop melanomas only.

It will be noted that the platyfish parents in mating *A* and *B* are ntical in color since they carried identical genes, *Rt* and *Sp*. Yet the F$_1$ brids they produced when mated to albino swordtails differed.

The production of the erythromelanoma in the platyfish-swordtail brids then depends upon the presence of the linked genes *Rt Sp*. These tails indicate the preciseness of the genetic (chromosomal) control of gment-cell development. They also show the importance of studying the rious genes and gene combinations and their specific developmental ects upon the normal and atypical growth of specific cells. From these periments it may be concluded that the spacial relationships of some nes as well as specific gene combinations influence the development of ecific tumors.

THE GENETIC BASIS FOR THE DEVELOPMENT OF OCULAR TUMORS

During 1943 to 1946 a number of platyfish, swordtails, and their hybrids our laboratory developed exophthalmic ocular tumors. Levine and ordon (1946) diagnosed the disease as a melanoma that developed from e pigmented choroid cells and invaded the retina and interocular region. bsequently it was discovered that Jahnel (1939) in Germany had found sentially the same disease in some members of a common brood of ybrid swordtails.

An analysis of our animals revealed that most of the exophthalmic shes with ocular melanomas were genetically related. Gordon (1946b) ggested that a recessive gene, *oc* for ocular tumors interacting with the lbino gene *a* was primarily responsible for the disease. In none of the yes of the affected fishes were extraneous organisms found.

CATARACTS TRACED IN FIVE GENERATIONS OF PLATYFISH

A female platyfish was discovered with a cataract in one of its eyes, linding it in that eye. It was mated to a closely related but normal male. ordon (unpublished) found that all of their offspring (first generation) ad normal eyes. When these were mated, they produced 43 second-generation fish 1 of which, a male, had a cataract. Unfortunately the cataractal male was unable to mate. Ten pairs of normal second-generation fish were mated. Three pairs each produced 1 cataractal fish in the third generation.

One of the cataractal females of the third generation when mated with its brother produced 5 broods totalling 115 fish of which 20 had cataracts. It was not possible to carry the analysis beyond the fourth generation. The distribution of the cataractal fish through 5 generations is so erratic that no clear-cut genetic analysis is possible. It may be said, however, that cataracts in the platyfish are inherited in a manner not yet determined.

GENETICS OF THYROID AND KIDNEY TUMORS

Marine and Lenhart (1910) and Gaylord and Marsh (1912) showed that thyroid tumors in hatchery-reared brook trout (*Salvelinus fontinalis*) developed from hypertrophied and hyperplastic thyroid tissue. The tumors invaded and replaced muscle and bone. Much later Gorbman and Gordon (1951) described a somewhat similar tumor in laboratory-reared Montezuma swordtails, *Xiphophorus montezumae,* originally obtained from the Río Panuco in Mexico.

The laboratory-reared swordtails have been propagated since their initial introduction in 1939 by methods described by Gordon (1950b). The fish were kept in conditioned fresh water that, for many years, had been used over and over again. This conditioned water was interchanged among the tanks containing members of six other species of xiphophorin fishes. The diet of all seven species of fishes contained dried shredded ocean shrimp, liver, cereal, and living tubificids and daphnids.

Later, Berg, Edgar, and Gordon (1953) described the genetic history and the developmental stages of the thyroid tumor in various sublines of inbred laboratory-reared Montezuma swordtails. The thyroid tissue of these fishes was also compared to similar glands obtained from wild swordtails taken from their natural habitat and fixed at the site of their capture, in Mexico. One laboratory strain called 38^3, represents 7 generations of inbreeding, the last 3 by brother-to-sister matings. The second strain, called 43, has a similar genetic history for the first 4 generations; the last 3 generations represent close inbreeding but not by brother-to-sister matings.

Baker and Gordon (1953) made some preliminary studies of the differential susceptibility of various strains of the platyfish, *Xiphophorus maculatus,* to a kidney tumor. The kidney tumors are cystic and show features of papillary adenoma, others of adenocarcinoma. The susceptibility of the platyfish to these tumors appears to be genetically determined. Under identical conditions of maintenance, various pure lines derived from wild populations and from fanciers' stocks have widely differing incidences of the disease. Estimates based on gross examination of hundreds of preserved specimens accumulated over several years from the laboratory-reared stocks, and of currently maintained animals, indicate that the incidence of the tumors may be very high (50 percent) in some lines and zero in others.

More recently, Baker, Berg, Nigrelli, Gorbman, and Gordon (1954) re announced that the thyroid glands of fishes with tumorous kidneys hyperplastic, extending dorso-ventrally from the floor of the mouth o the jaw muscles, laterally to the gills, and posteriorly to the heart. yroid cells infiltrate along muscle fascia and larger blood vessels into the roid gland of the eye, the pericardium, and kidney, but not the liver. ll continuity between thyroid and kidney tumors is traceable along the f of the pericardium and cardinal sinuses. Radioactive iodine injected o tumorous fishes yielded definite radioautographs from cross-sections rough the kidney and thyroid regions.

GENERAL COMMENTS AND CONCLUSIONS

Positive evidence that heredity plays an important role in the development of cutaneous melanomas by the platyfish-swordtail group of fishes s been obtained independently by Kosswig, Breider, and Gordon (for ferences, see Gordon, 1951). Hereditary factors are also important in the velopment of ocular melanomas. Apparently the latter is unrelated netically to the former. Some of the principle genes responsible for the velopment of these diseases have been identified; the most thoroughly alyzed one is that of the cutaneous melanomas.

The results of all the genetic experiments concerned with normal and ypical pigmentcell growth in fishes may be explained within the frame-ork of present-day principles of mendelian inheritance. The hereditary ontrol of melanomas in hybrid fishes rests not on one gene but on a con-ellation of genes. To be effective this assemblage of genes must contain ithin it a gene for macromelanophores, the pigment cells that are sensi-ve to the influence of genic imbalance.

The spontaneous thyroid tumors and kidney tumors are apparently nder genetic influence, but the actual genes involved have not yet been entified.

A gene responsible for abnormal spines has been discovered in a number fishes. Many of the variations of the goldfish would be regarded as being bnormal, if they occurred in other species. Many of these abnormalities of he goldfish, according to a review by Gordon (1950b), are inherited in a omplex manner. From time to time numbers of individuals of a single pecies of fish in nature are reported to have similar abnormalities; some or example, have no anal fins, some are susceptible to a particular disease. s an illustration, Schlumberger (1950) reported that 5 percent of the oldfish in a large urban pond developed cutaneous neurofibroma and some lso had polycystic kidneys. He suggested that possibly genetic factors were nvolved.

Abundant evidence thus exists for the genetic control of certain diseases nd abnormalities in fishes. The known facts with respect to fishes parallel hose known for genetic control of diseases and abnormalities in other ertebrate animals including man. The hereditary factors involved in dis-ase and structural abnormalities are generally complex and difficult to detect, but the evidence for their existence is undeniable.

Given the time, sufficient financial support, an adequate and modern program of research, the fish geneticist could match, with fishes, the spectacular successes that plant and non-ichthyological animal geneticists have had in the improvement of their farm plants and land animals.

A series of articles on the principles of inheritance for the fish fancier has been prepared by Gordon (1952–1954).

ACKNOWLEDGMENT

I am indebted to James W. Atz and K. France Baker of the New York Zoological Society for aid in the preparation of the original draft of the manuscript and to Dr. S. F. Snieszko for this version. I also thank The American Museum of Natural History for use of its laboratory facilities.

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THE NATURE OF BACTERIA PATHOGENIC TO FISH

Philip J. Griffin

Microbiological Laboratory
U. S. Department of the Interior, Fish and Wildlife Service
Leetown, West Virginia[1]

Abstract

A review is made of the progress in research on bacteria which are pathogenic o fish, with particular emphasis on those investigations performed during the ast decade. The report includes a critical review of material published; the omments and suggestions are designed to stimulate the initiation of new research rojects.

Introduction

Many microorganisms found in and associated with water have proved great value as implements to further knowledge of a fundamental aracter. More is to be learned of the nature, physiology, and relation of ese diminutive plants to other forms of life, particularly with reference the phenomenon of diseases in cold-blooded animals.

The bacteria discussed in this paper are principally those most widely cognized as causes of fish diseases. As few microbiologists are enged actively in research on the nature of fish pathogens, there is a ucity of data to review. Nevertheless, encouraging progress has been ade during the last decade—enough to allow one to view the future with thusiasm.

Myxobacteriales

The myxobacteria may be considered as "higher bacteria" because of ructural and/or developmental features analogous to those of certain ther forms of life. The microorganisms are usually long, slender, flexible, onflagellated vegetative cells which on occasion lead an unusual type of ommunal existence. The cells are surrounded by quantities of a slimy atrix which imparts a moist appearance to the colonies. These "colonial ells" characteristically exhibit a gliding or slithering motion and the inividuals frequently move *en masse*. Most possess a relatively complex fe cycle which, for convenience, can be divided into a "swarm state" nd an "encystment stage". In the former, the vegetative cells may be arallel, singly or in groups. In the final stage, the formation of cysts and hen fruiting bodies occurs among members of certain families of this rder. The rods may gather at various loci and pile up on the surface to

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P O. Kearneysville, West Virginia. Present address of author—Department of Biochemistry, ale University, New Haven, Connecticut.

form stalk-like structures on the ends of which the fruiting bodies develop (the slimy matrix apparently dries and the cells are thus encysted to form the body). Favorable growth conditions may then influence the fruiting structures to break open; the bacteria move out into the surrounding medium, new slime-covered colonies are formed, and the "swarm state" begins anew. Most members of this peculiar group are only saprophytic and can be found in manure, soil, rotten wood, straw, ...

Columnaris disease.—An exception is those myxobacteria reported to be pathogenic for fish. Davis (1922) was possibly the first to recognize an organism which caused a "mold-like" growth on the skin and fins of fish which were held in aquaria. The microorganism was described as a long, slender, flexible rod which exhibited a peculiar sinuous movement. The organisms collected together about a fragment of scale debris for example, to form short columns or dome-shaped masses (hence the name "columnaris disease"). These observations suggested that these organisms were members of the Myxobacteriaceae, but at the time of Davis' report little was known of this unique group and the now familiar name, *Bacillus columnaris*, was therefore aptly applied. A discussion of the myxobacteria by Rucker, Earp, and Ordal can be found in another section of this symposium.

Gill Diseases.—Like pneumonitis in man, the term gill diseases is to be preferred over the singular designation, gill disease. The discussion will be limited to those instances in which bacteria have been consistently associated with impaired gill function. It is difficult to discuss the nature of the associated microorganisms since the etiology is still obscure. Ordal and Rucker (1944) isolated myxobacteria, which did not produce fruiting bodies, from the gills of infected fish. From the discussion of Rucker, Johnson, and Kaydas (1952), it would appear that the filamentous bacteria associated with this disease are not necessarily all of the same type. In the same paper these authors referred to the observations of Burrows concerning a bacterium which formed plaque-like colonies on the gill filaments. Typical filamentous bacteria were noted in association with the plaques, the latter disappeared, and only the filamentous microorganisms remained. This description finds an analogy in the phenomenon of columnar formation in columnaris disease.

At this time all attempts to transmit the disease artificially have failed. This fact in itself does not preclude the possibility that these bacteria are the agents of a type of gill disease since similar difficulties exist in certain other diseases (*e.g.*, syphilis, leprosy) in which the organism, once cultured, somehow loses some or all of its pathogenic qualities.

Aeromonas salmonicida (Furunculosis)[2]

Little has been published on the nature and characteristics of this microorganism in the last decade. The reader is referred to the excellent review of furunculosis by McCraw (1952) for previous research on this bacterium.

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[2] In the next edition of Bergey's Manual of Determinative Bacteriology, *Bacterium salmonicida* will be placed in the new genus *Aeromonas*, (Kluyver and van Niel).

'he first significant diagnostic method in detecting furunculosis came
ı the formulation of a casein digest-yeast extract medium (Gutsell
Snieszko, 1949) which is particularly suited to demonstrate the
racteristic amber-black pigment produced by this bacterium. The pig-
ıt is used as the criterion for the presumptive bacteriological diagnosis
he disease. Although the method is highly reliable, diagnosis is condi-
ıal since other microorganisms are known to produce similar pigments
ark and Smith, 1939; Ensminger, 1953; Klykov, 1945; Ungerer, 1934).
example, *Pseudomonas calco-acetica*[3] slowly produces a pigment in a
nner almost indistinguishable from that of *A. salmonicida*. A differ-
iation could be made, however, by applying paraphenylenediamine to
surface of the colonies (Griffin, 1952c; Griffin, Snieszko, and Friddle,
3c). In conjunction with motility tests, the procedure serves adequately
a presumptive test for *A. salmonicida* even *before* a pigment develops.
n view of the widespread occurrence and economic importance of
unculosis, a curious anomaly existed: the microorganism was first
lated and described nearly 60 years ago but until recently a complete
scription was lacking. Consequently only a superficial reference can be
ınd in Bergey's Manual (Breed, Murray, and Hitchens, 1948). Accord-
ly, an investigation was undertaken to establish descriptive data to be
ed as a reference in the identification of the microorganism. The details
y be found in the publication of Griffin, Snieszko, and Friddle (1953a).
In the choice of a medium for the bacteriological diagnosis of furuncu-
is in fish, the process of pigmentation assumes considerable importance.
ailability of oxygen, proper temperature of incubation, and suitable
mposition of the medium are essential to pigment formation. L-tyrosine
L-phenylalanine are the parent compounds in the formation of the
lanin-like pigment (Griffin, 1952b). Other substances will also act as
bstrates for the enzyme or enzyme systems in *A. salmonicida*, as for
ample, D-phenylalanine, glycyl-L-phenylalanine, and B-2-thienylalanine
ich can substitute for L-phenylalanine; L-tyrosine ethyl ester and
ycyl-L-tyrosine can be substituted for L-tyrosine. The color and intensity
the resultant pigments vary according to the material used. To cite
ıt one example, a bright salmon-pink color is produced through the use
B-2-thienylalanine. That the pigment is a result of phenylalanine and
rosine metabolism has been conclusively proven since pigmentation does
ot occur in a defined medium which lacks the amino acids or various
ıbstituents indicated above (Griffin, Snieszko, and Friddle, 1953b).
hese same authors also suggested the conversion of phenylalanine to
rosine which was recently demonstrated by Mitoma (1954). The same
onversion occurs in humans but few, if any, other bacteria have been
ported to have this capacity.

The problem of the properties which give *A. salmonicida* its pathogenic
uality is exceedingly complex; indeed, a complete explanation has not
een found even in studies of other bacterial diseases.

One method of approach to understanding is offered by direct study of
ne disease agent itself; the observations of the requirement by *A. sal-*

Culture obtained from Dr. W. C. Haynes, U. S. Department of Agriculture, Peoria, Illinois.

monicida for the amino acid arginine may be taken as a case in point. A common pathway in the metabolism of arginine by certain other microorganisms is its conversion to ornithine. A simple decarboxylation of these products would form agmatine (from arginine) and putrescine (from ornithine). Tyrosine, shown to be important in pigmentation, might also be decarboxylated to tyramine. These substances are physiologically or pharmacologically active and, if formed, would play a role in the disease process. For example, agmatine possesses insulin-like properties; the effect of this amine would be to remove glucose from the blood stream. Field *et al.* (1944) have presented evidence for a dramatic hypoglycemia in fish with acute furunculosis. It was suggested that the microorganism utilizes the blood sugar in its metabolism (the fermentation of glucose has been demonstrated *in vitro* by various investigators) and that the hypoglycemic shock thus induced, contributes to the fatalities. Increased urea and creatine values also found by these same investigators probably reflect the extreme tissue destruction caused by proteolytic enzymes produced by *A. salmonicida*. The presence of larger amounts of creatine is significant since it apparently indicates disintegration of muscle tissue. Although *A. salmonicida* produces a hemolysin, the contribution which this enzyme makes to the pathology is small since Field *et al.* (1944) indicated that hemoglobin and erythrocyte values (in fish inoculated with *A. salmonicida*) were essentially the same as those found in the uninoculated controls.

Davis (1946) noted that furunculosis is particularly common among mature trout during and shortly after the spawning season. The usual explanation is that the exacerbation of disease is primarily a consequence of rough handling of the fish when spawn is taken. This view appears logical enough and undoubtedly handling is an important factor; however, other possible influences should be considered. Arginine is intimately involved in the growth of *A. salmonicida*, and so also are histidine, asparagine, lysine, methionine, and probably leucine.[4] It is striking that, except for leucine and methionine, all the other amino acids concerned in the *in vitro* growth of *A. salmonicida* are predominantly basic in reaction. In an actual infection, these amino acids are supplied to the organism by the fish. Protamines, the characteristic proteins of ripe sperm cells (*e.g.*, salmine from salmon, clupeine from herring, . . .), are especially rich in basic (diamino) amino acids (arginine for example, constitutes approximately 87–91 percent of the total nitrogen in clupeine). The "carrier state" and latent infections have been shown to exist in furunculosis and to represent delicate balances between host and parasite. Any condition tending to affect the fish adversely, *e.g.*, low oxygen, poor diet, infestation, would necessarily disrupt the delicate adjustment and favor the pathogen. Conversely, anything tending to enhance the growth and development of the microorganism might have the same effect. Once part of the metabolic machinery of the fish is turned to the production of these basic amino acids, a more favorable environment is created for the microorganism.

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[4] P. J. Griffin and associates, unpublished observations (1953).

he Furunculosis Committee isolated *A. salmonicida* from the ovaries nfected trout (McCraw, 1952); it would be desirable to look for these anisms in testes also. Some support for the belief that the pathogen occur in the testes comes from the observations on an outbreak of unculosis by Stevens and Keil (1931); just prior to the spawning son, a large number of fish developed lesions and the progress of the ease was rapid, particularly among the male fish. Similar observations e been made by others.

constant feature of furunculosis is the absence of marked leukocytic ltration. Blake (after McCraw, 1952) indicated that blood films show- considerable numbers of free bacteria and relatively little phagocytosis. ld and associates (1944) stated that the blood picture in fish inoculated h *A. salmonicida* was essentially the same as that found in the control mals. This is anomalous in view of the widespread tissue involvement ident to this disease. Possibly the absence of chemotaxis means that the anism produces a leukocidin; a type of histone may be involved; the nonstration of hyaluronidase ("spreading factor") also would add to enlightened understanding of the pathogenesis.

The difference noted in the leukocytic response of fish to the agent of er disease suggests a convenient method of diagnosis, since in this ease, as opposed to furunculosis, a marked leukocytic infiltration is a istant feature. Total white blood cell and differential counts may be of ue in predicting the disease even before obvious external symptoms hich are frequently misleading) appear and bacteriological examinations made. Although cases of mixed infections might be confusing, such an roach might indeed prove to be fruitful.

Older concepts of disease as the result of mechanical action alone are, course, no longer acceptable (Bodansky and Bodansky, 1952). Possibly tain additional concepts of mechanical defense against infection in h as, for example, an intact slime layer as a physical barrier to infectious ents, may need some modification. Protective substances such as sozyme in tears, inhibine in saliva and virus-inactivating agent (V.I.A.) nasal secretions, are known. Similar bacterial antagonists may occur in slime which surrounds the fish.

Hemophilus Piscium (ULCER DISEASE)

The name "ulcer disease" generally has been applied to a number of seases of fish characterized by external ulceration. Snieszko (1952) ggested that the term be restricted to that condition caused by *Hemo- ilus piscium* and having the symptoms and pathology described by Fish 934) and Wolf (1939). This restriction serves to establish the nature d agent of this disease and thus eliminates confusion with ulcerative nditions caused by a host of other microorganisms. This limitation is portant since Davis (1946) indicated that brook trout (*Salvelinus ntinalis*) inoculated with *A. salmonicida* by pricking the skin with a eedle, developed lesions identical with those from typical ulcers of a atural infection. Reed and Toner (1941) reported a "red sore" disease in northern pike (*Esox lucius*) and in brook trout; however the organism isolated was *Pseudomonas hydrophila* (*Aeromonas liquefaciens* according to the new nomenclature). Flakas (1950) recovered both a gram positive rod and *A. salmonicida* from ulcerative lesions on yearling brook trout. The suggestion of some synergistic action was made but the hypothesis was not tested further.

Snieszko and Friddle (1950) first isolated *H. piscium* from the ulcers, blood, and kidneys of diseased fingerling brook trout by utilizing a medium enriched with blood or other natural products. A complete description of the microorganism soon followed (Snieszko, Griffin, and Friddle, 1950). The need for a thermolabile factor, essential to growth, was indicated. Griffin (1951) reported that a phosphorylated moiety was involved and that diphosphothiamine (cocarboxylase) and adenosine triphosphate (ATP), in exceedingly low concentrations could substitute for crude materials. The same author (1952a) indicated that in the presence of cocarboxylase or ATP, the growth response to the thermostabile compound hemin (X factor) was comparable to that in media containing crude substances. Adenosine monophosphate and adenosine diphosphate were found capable of supporting growth to varying degrees and curiously, thiamine proved inhibitory. Either the phosphorylated derivative of thiamine (cocarboxylase) or ATP was capable of reversing the inhibition.

Ulcer disease in fishes has a striking counterpart in tularemia in humans, especially in the clinical type of tularemia known as ulceroglandular. In this disease, the organism (*Pasteurella tularense*) is retained at the site of the local lesion for a period of days—probably a result of mechanical effects of local inflammation and the host's immune response. The primary lesion usually appears at the point of a microscopic scratch or cut. In 3 or 4 days a papule forms and by 7 or 8 days an open ulcer develops. (The reader is referred to the descriptions of ulcer disease given by Wolf (1939) and Davis (1946) for comparison). This remarkable similarity may be more than fortuitous since both *Past. tularense* and *H. piscium* require the same thermolabile growth factors (Tamura and Fleming, 1949; Griffin, 1951). Possibly a greater familiarity with pathogenesis in tularemia would lead to a better understanding of the process in ulcer disease.

INFECTIONS CAUSED BY PSEUDOMONADS

Members of this group are gram negative, usually polar-flagellated bacilli, widely distributed in nature, and frequently productive of water-soluble pigments. Many members of this genus are pathogenic for both marine and fresh-water fishes.

Wells and ZoBell (1934) described an infective dermatitis in certain marine fishes caused by *Achromobacter ichthyodermis*. Later, ZoBell (1946) indicated that the organism should be designated *Pseudomonas ichthyodermis,* since it possessed a polar flagellum. Fish (1934) reported the presence of *Proteus hydrophila* in an ulcerative condition of brook trout and Wolf (1937) tentatively identified *Ps. fluorescens* as the etiologiagent of an air bladder disease of lake trout (*Salvelinus namaycush*) erlings.

n Germany, Schäperclaus and Mann carried out extensive studies on p (*Cyprinus carpio*) dropsy. Their results are summarized in a mono- ph (Mann, 1939; Schäperclaus, 1939; Schäperclaus and Mann, 1939). estigations on the same disease were carried out by Snieszko *et al.* Poland (1938; English summary, 1940) who isolated the same micro- anism (*Ps. punctata*) and reported that the biological characteristics of isolated cultures were identical with those described by Schäperclaus. e bacteria isolated in Poland formed a serologically heterogeneous up. An interesting work on the immunization of carp with *Ps. punctata* s published by Mann (1939).

Although the symptoms of the disease in carp often were variable, the st frequent extreme signs were deep ulcers penetrating the skin and derlying musculature and a dropsical condition which, according to ne, is caused by a variant (*Ps. punctata v. ascitae*). The final stage of disease is a general septicemia.

Schillinger (1949) discussed the efficacy and practicability of immuniz- carp against septicemia. A similar topic was treated by Marek (1950). ed and Toner (1941) isolated *Ps. hydrophila* from the organs and blood northern pike suffering from "red sore" disease. These same authors 942) again isolated the organism from northern pike, brook trout, and gs and suggested that frogs act as carriers of the organism from one dy of water to another. The organism is identical with the etiological ent of "red leg" in frogs and through the years, a variety of generic and ecific names have been applied. The following are synonyms: *Bacillus nicida*, *Bacillus hydrophilus fuscus*, *Bacterium hydrophilus fuscus*, *oteus hydrophilus*, and *Pseudomonas hydrophila*. Kulp and Borden 942) pointed to the presence of polar flagellation, indicating that the neric name *Proteus* did not apply. Guthrie and Hitchner (1943) found w significant differences between the characteristics of strains classified *Proteus hydrophilus* (that had been isolated from frogs, northern pike, d trout) and those of *Pseudomonas punctata*. Stanier (1943) states at *P. hydrophilus* should be termed *Aeromonas hydrophila* because of e vigorous manner which these organisms ferment carbohydrates. nieszko[5] compared the characteristics of various cultures of bacteria scribed as *Pseudomonas punctata*, *Proteus hydrophilus*, *Pseudomonas drophila*, *Proteus melanovogenes* (Miles and Miles, 1951), *Aerobacter quefaciens*, *Pseudomonas hirudinis* (Büsing, 1952), and a number of her cultures of monotrichous, carbohydrate-fermenting bacteria isolated om water and from healthy and infected fish. From this study he con- uded that all of these bacteria belong to the same species and that on e basis of rules of bacterial taxonomy, the name *Aeromonas liquefaciens* ould be applied.

Hodgkiss and Shewan (1950) recorded an infection in a plaice (*Pleuro- ectes platessa*) caused by what they regarded as *Pseudomonas ichthyo-*

S. F. Snieszko, unpublished observations (1953).

dermis. Margolis (1951) reported a hemorrhagic septicemia in norther pike ("red sore" disease) caused by *Ps. hydrophila*. The organism was re covered from the intestines and slime of several other fish, none of whic showed any signs of the illness. Rucker and Whipple (1951) isolated pathogenic fluorescent pseudomonad from yearling sockeye salmo (*Oncorhynchus nerka nerka*) and Seaman (1951) described a pathogeni pseudomonad isolated from rainbow trout (*Salmo gairdneri*). A definit taxonomic position was not assigned to the organism because of the lac of additional experimental data. Wagner and Perkins (1952) also isolate a Pseudomonad from infected rainbow trout. The disease was referred t as "red mouth" disease and the offending microorganism was characterize as *Ps. hydrophila*. Brunner and Striegel-Jaxtheimer (1951) isolated *P* *punctata* from carp with infectious dropsy, however, another bacteriun ("Bacterium münchen") was isolated from the majority of the fish. Thi organism was not identical with either *Ps. punctata* or *Ps. hydrophila*. A important event was the isolation of "Bacterium münchen" from th copepod, *Argulus foliaceus*, which had sucked blood from diseased carp This mode of transmission has interesting implications not only with re spect to the transmission of carp dropsy but for other diseases as well Brunner and Striegel-Jaxtheimer (1953), after additional studies o "Bacterium münchen", concluded that this microorganism is distinct fron *Ps. punctata* and represents a new species. The name *Pseudomonas granu lata* was applied. Dombrowski (1953a; 1953b) disagreed with the forme authors and considered the differences to be too slight to justify the namin of a new species. Schäperclaus (1939) suggested the possible involvemen of a virus in this disease, possibly in association with *Ps. punctata* Roegner-Aust, Brunner, and Jaxtheimer (1950) reported that infectiou dropsy of carp is primarily viral. The virus-like particles were seen unde the electron microscope inside the infected, and apparently normal, carp eggs. This observation suggests the possibility of the transmission of thi disease by means of eggs. Marek (1950) also alluded to reports of Soviet investigators who consider a virus as the primary cause of carp septicemia and a recent work by Brunner and Zöbe (1953) lends additional support to this view. However, Dombrowski (1953c) questioned the viral etiolog of this disease. Wunder and Dombrowski (1951) reported on the transmission of carp dropsy by parasitic copepods and leeches. On the basis of the above information, and the fact that many of the terrestrial invertebrate animals serve as carriers of virus diseases for other groups of animals (or even plants) one can speculate on the role of many parasites in the transmission of bacterial and viral diseases of fishes.

MISCELLANEOUS DISEASES

This section concerns those diseases of fish to which reference is made only infrequently, either because the diseases are not widespread or occur frequently but are not generally recognized.

Tuberculosis.—It is questionable whether tubercle-like lesions in fish are related to tuberculosis in higher animals. Nevertheless, the lesions do

mble more or less those found in classical tuberculosis, and acid-fast
lli are implicated. Since only a few cultures of such microorganisms
e been studied, it is equivocal whether those reported are actually mem-
of different species. Reports of Mycobacteria found in fish are record-
y Aronson (1938). Baker and Hagan (1942) isolated *Mycobacterium*
ypoecilus from Mexican platyfish (*Platypoecilus maculatus*) and
relli (1943) found acid-fast bacilli in tropical fish of various genera
species. More recently, Earp, Ellis, and Ordal (1953) reported acid-
bacilli in enormous numbers in adult chinook salmon (*Oncorhynchus*
awytscha) showing gross kidney lesions. The question of the possible
ortance of tuberculosis caused by "cold-blooded" mycobacteria in
ine habitats was raised.

idney Disease.—The disease, characterized by white, raised areas of
rotic tissue, particularly in the kidney, is caused by small gram-positive,
motile, diplobacilli which are usually less than 1 micron long. The or-
isms occur intra- and extracellularly. They are not filterable and have
n reported as culturable *in vitro* (Earp, Ellis and Ordal, 1953). Belding
Merrill (1935) were possibly the first to describe the disease. How-
r, the organism which they isolated was motile and upon inoculation
fish did not reproduce the disease they observed in the natural in-
ion. The organisms have been found in brook trout, brown trout
lmo trutta) and rainbow trout and also in sockeye salmon (Ordal and
p, 1950; Earp, 1950[6]; Rucker, *et al.*, 1951). At present, the taxonomic
ition of this microorganism is uncertain.

Mohamed (1939) observed intra- and extracellular minute bodies in the
od of a dead fish which had necrotic ulcers on its body. The organisms,
ute coccoid forms varying from 0.2 to 0.4 micron in diameter, fre-
ntly occurred in pairs, and were seen inside monocytes and also in
plasma. Mohamed gave these organisms the name *Rickettsia pisces*
l stated that his report contained the first published record of a
kettsia in fish. This disease appears to resemble "kidney disease" in
s country.

few other microorganisms, isolated within the last decade or so, have
n described inadequately or are still of an undetermined taxonomic
ition. Flakas (1950) isolated a motile, gram-negative, microaerophilic
illus from infected black crappies (*Pomoxis nigromaculatus*) and ten-
ively assigned it to the genus *Spherocillus*. The lesions produced in this
ease were relatively wide, swollen, hemorrhagic areas which appeared
only one side of the body, behind and slightly above the pectoral fin.
e description of the lesion site coincides with that given by Griffin and
ieszko (1951) of an infection of tropical fish caused by a motile, gram-
ative bacillus which proved to be a facultative anaerobe. This organism
of unique taxonomic position in that biochemically it resembles *Para-*
lobactrum aerogenoides; however, the presence of a single flagellum
ces it in the genus *Pseudomonas*. According to unpublished work recently

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arp, B. J. 1950. Kidney disease in young salmon. 65 pp. [Typewritten thesis; University of
shington]

completed by Snieszko (1953), this bacterium is identical with *Aeromona* *liquefaciens* (*cf.* above). Margolis (1951) reported the isolation of peritrichic, gram-negative bacillus from a diseased white sucker (*Catosto-mus commersoni*). This bacterium was classed as a member of the genus *Paracolobactrum.* It is practically identical in all other respects to the monotrichic form described by Griffin and Snieszko (1951).

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FISH DISEASES AND NUTRITION

John E. Halver

Salmon Nutrition Laboratory
U. S. Department of Interior, Fish and Wildlife Service
Cook, Washington

Abstract

Malnutrition in fish population, although recognized by the earliest workers in fish culture, has only recenty received intensive study commensurate with that in other fields of animal nutrition. Recent experimental test diets have produced specific deficiency syndromes for most of the vitamins and have indicated the possibility of developing specific deficiencies for amino acids, fatty acids, and other basic nutrients. During the past 3 years the first evidence of susceptibility to bacterial disease in lots of fish with sub-clinical manifestations of vitamin deficiencies has opened an entire new field in fish-disease study.

In this review (a portion of a symposium on fish diseases) the nutrition of salmonids is emphasized. Advancements within the last 10 years in the fields of avitaminosis, hypervitaminosis, susceptibility to disease and general malnutrition are mentioned and a table is included which compares the specific avitaminosis syndromes observed in fish with those observed in other experimental animals.

Introduction

Malnutrition in fish populations, although recognized by the earlies workers in fish culture, has only recently received intensive study commensurate with that in other fields of animal nutrition. Heretofore, attempts t investigate the role of specific nutrients in fish nutrition have been hampered by the lack of suitable test diets in which the factors in questio could be controlled experimentally. Recent experimental test diets hav enabled investigators to produce specific deficiency syndromes and hav laid foundations for controlled study of fish nutrition. Within the last years, the first indications of susceptibility to bacterial disease in fis showing sub-clinical manifestations of specific vitamin deficiencies hav opened an entire new field in fish-disease study. These advances promis an increased activity in the study and establishment of the nutritional requirements of fish; and the description, detection, and prevention of nutritional-deficiency syndromes may be made on a more rational basis in th near future.

In this review of the advancements in fish nutrition within the last 1 years, only the nutrition of salmonoid fishes will be discussed because thi group is available for close examination in artificial environmental conditions and is one on which there is sufficient literature to warrant a review In the natural state probably only sub-clinical manifestations of nutritional deficiencies appear because the natural food supply is rich in th

c nutrients and growth factors. Under hatchery conditions, however,
re economy demands the use of artificial diets, nutritional deficiencies
become a serious problem. Detection and prevention of the deficiency
dromes not yet adequately described remain difficult since the specific
itional requirements of fish of various species have not been estab-
ed. Sub-clinical deficiency syndromes are at present the greatest prob-
and until better detection methods are developed, or until the nutri-
al requirements are defined for the species, no practical diet can be
nulated with assurance of nutritional balance.

AVITAMINOSIS

nvestigations of the role of vitamins in fish nutrition and observations
general vitamin deficiency syndromes were well established more than
years ago and still continue actively. A number of workers observed
hiamin deficiency in trout and salmon when a portion of the diet con-
ed of fresh or freshly frozen fish tissue (Tunison *et al.*, 1942; Wolf,
2; Woodbury, 1943; Burrows, Robinson, and Palmer, 1951). Simmons
Norris (1941) reported that an anemia in young silver salmon,
orhynchus keta, and chinook salmon, *Oncorhynchus tshawytscha*, could
cured by injecting xanthopterin, and other workers prevented an
mia in brook trout, *Salvelinus fontinalis*, by feeding a mixture of ribo-
in, pyridoxine, and pantothenic acid (Tunison *et al.*, 1943). By chang-
the proportions of the different ingredients in the ration, tentative vita-
requirements for rainbow trout, *Salmo gairdneri*, brown trout, *Salmo*
tta, and brook trout were determined (Table 1).

The possibility of a test diet was seen by workers developing a meatless
on for trout (McLaren, Herman, and Elvehjem, 1946), and a diet con-
ing of commercial casein, starch, fish-liver oils, crab meal, minerals, and
mins was formulated (McLaren *et al.*, 1947b). Deficiency syndromes
some of the water-soluble vitamins were reported for 4-month-old rain-
v trout by McLaren *et al.* (1947a). The descriptions of the various
cific vitamin-deficiency syndromes are presented in Table 2. Feeding
ls with salmon fingerlings and more prolonged feeding periods with
ut failed to substantiate the adequacy of the McLaren test diet without
esh-liver supplement (Rucker, Johnson, and Kaydas, 1952).

A diet was developed which could be used to develop vitamin deficiencies
rout for some of the water-soluble vitamins (Wolf, 1951). The need for
ntothenic acid, inositol, and folic acid was demonstrated but no
iciencies could be shown when niacin, biotin, ascorbic acid, vitamin
, vitamin K, or vitamin E were individually omitted from the diet.
cept for a short feeding trial, sufficient to develop a pantothenic-acid
iciency (Rucker, Johnson and Kaydas, 1952), the diet was not tested
salmon fingerlings.

Work with chinook salmon made it apparent that existing diets could
t be used during the short fresh-water feeding period because the resi-
al vitamin activity in the basal ration prevented the development of a
ficiency syndrome for certain vitamins. A vitamin-free basal ration was

TABLE 1.—*Vitamin requirements of trout*

Vitamin	Species	Milligrams per kilogram body weight per day	Author
Thiamin	Brook	0.15 — 0.19	Phillips *et al.*, 1946
	Brown	0.15 — 0.19	Phillips *et al.*, 1946
	Rainbow	0.15 — 0.19	Phillips *et al.*, 1946
Riboflavin	Brook	0.44 — 0.68	Phillips *et al.*, 1946
	Brown	0.44 — 0.68	Phillips *et al.*, 1946
	Rainbow	0.44 — 0.68	Phillips *et al.*, 1946
Pyridoxine	Unknown	0.23 — 0.25	Tunison *et al.*, 1944
Pantothenic acid	Unknown	1.11 — 1.45	Tunison *et al.*, 1944
	Brook	0.99 — 1.25	Phillips *et al.*, 1945
	Brown	0.99 — 1.25	Phillips *et al.*, 1945
	Rainbow	0.97 — 1.25	Phillips *et al.*, 1946
Niacin	Brook	3.0 — 4.1	Phillips *et al.*, 1947
	Brown	3.0 — 4.1	Phillips *et al.*, 1947
	Rainbow	3.0 — 4.1	Phillips *et al.*, 1947
Biotin	Brook	0.01 — 0.03	Phillips *et al.*, 1947
	Brown	0.04 — 0.08	Phillips *et al.*, 1947
	Rainbow	0.01 — 0.03	Phillips *et al.*, 1947
Folic acid	Brook	0.15 — 0.18	Phillips *et al.*, 1949
	Brown	0.15 — 0.18	Phillips *et al.*, 1949
	Rainbow	0.15 — 0.18	Phillips *et al.*, 1949

developed (Halver [1]) which contained only small traces of residual vitamin activity. This ration supplemented with crystalline vitamins proved successful in developing vitamin-deficiency syndromes in salmon for thiamin riboflavin, pyridoxine, choline, pantothenic acid, inosital biotin, folic acid and niacin (Halver,[1]). Inconclusive results were obtained for vitamin B_{1} and, under the experimental conditions, no need was demonstrated for para-aminobenzoic acid or ascorbic acid (Table 1). In addition to the vitamin-deficiency studies with salmon, a group of rainbow trout was reared through one reproductive cycle on the complete test diet to detect any deficiencies in the reproductive-vitamin content. Egg production and fertility proved normal in the mature fish. It should be valuable to use this diet to repeat previous tests for development of specific vitamin-deficiency syndromes in other species of trout and salmon.

HYPERVITAMINOSIS

Hypervitaminosis can be expected in fish as well as in other experimental animals when excessive quantities of certain oils or fats containing large amounts of the fat-soluble vitamins are fed. At least one report of hypervitaminosis A is present in the literature (Burrows *et al.*, 1952) when whale liver was used as a component of the diet. The diagnosis of the cal hypervitaminosis A syndrome involving nervous disorders and eye .mmation was supported by the extremely high vitamin A content re- ed by analysis of the diet. Similar results are possible if other rich rces of fat-soluble vitamins are included in the diet. The probability of eloping hypervitaminosis of any of the water-soluble vitamins is remote, ever, since they are so easily eliminated from the body that extremely ı concentrations of the pure vitamin itself would be required before the ervitaminosis syndrome would appear.

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[1] Halver, John E. 1953. A vitamin test diet for chinook salmon; the water-soluble vitamin requirements of chinook salmon. Ph.D. thesis; University of Washington. 82 pp.

Susceptibility to Infection

'he state of nutrition of the individual determines to a large extent the stance of the animal to bacterial infection. Although other factors play portant roles in the production of antibodies in fishes (Snieszko, Wolf, s symposium) the defense mechanism of the animal demands the exis- ce of adequate amounts of basic nutrients and precursors before these ibodies can be produced. If only one essential component is lacking or present in inadequate amounts, the production of protective antibodies severely hindered, allowing the bacterial infection to flourish. One of the st definite observations of lowered resistance in fish suffering a specific taminosis has recently been reported by Halver (1953). Further ob- vations, although not detailed in this paper, indicated that folic acid ıyed an extremely important role in resistance to infection. For 3 con- cutive years, those lots of fish on folic acid-deficient diets were the first exhibit myxobacterial infections, whereas other groups on the same ter supply were affected only mildly. Of interest also is the role of ositol in "fin rot" and of biotin in "blue slime patch disease." Much rk remains to be done before the role of vitamins in the prevention of sease can be defined, but current work in several laboratories should con- bute to the solution of this problem in the near future. Now that ex- rimental control of the nutritional components of diets is possible, inten- ve efforts can be directed toward determining the relationship between sistance to disease and nutritional balance.

General Malnutrition

In this review discussion of the immense amount of general data on ractical fish diets will be omitted and emphasis placed on specific mal- ıtrition syndromes.

One of the earliest observations on degeneration of the pancreas and ırrounding tissue was recorded when excessive amounts of fat, or fat and arbohydrate were fed to trout (Hess, 1935) and chinook salmon (Don- ldson, 1939).[2] The number of islets of Langerhans was severely reduced nd fatty infiltration of the liver also occurred in some fish. Donaldson howed that cholesterol produced degeneration of the pancreatic tissue in

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Donaldson, Lauren R. 1939. Experimental studies in the nutrition of the chinook salmon with pecial reference to histological changes in the pancreas. Ph.D. thesis, University of Wash- ıgton. 62 pp.

TABLE 2.—*Vitamin-deficiency syndromes*

[The numbers in parentheses refer to authorities listed in notes at bottom of table]

Vitamin deficiency	Signs of avitaminosis	
	In salmon and trout	In other animals
Thiamin	Poor appetite; muscle atrophy; convulsions prior to death; instability and loss of equilibrium; anorexia (1, 2, 3, 4). Generalized edema (4).	Poor appetite; muscle atrophy; convulsions in most acute stage; generalized edema; instability and loss of equilibrium; anorexia; brain lesions; degeneration of peripheral nerve fibers; impaired carbohydrate metabolism (6, 7).
Riboflavin	Corneal vascularization; cloudy lens, hemorrhagic eyes (1, 4). Photophobia; dim vision; incoordination; abnormal .pigmentation of iris; striated constriction of abdominal wall; dark coloration; poor appetite (4).	Corneal vascularization; cloudy lens; hemorrhagic eyes; cataracts photophobia; dim vision; incoordination; abnormal pigmentation of iris; scleral congestion; cheilosis and angular stomatitis; impaired erythrocyte formation (6, 7).
Pyridoxine	Nervous disorders; epileptiform fits (1, 4). Light spots on liver (1). Hyperirritability; ataxia; anemia; loss of appetite; edema of peritoneal cavity; colorless serous fluid; spastic convulsions; blue-green coloration on back; *Post-mortem rigor mortis* occurs rapidly; rapid and gasping breathing; flexing of opercles (4).	Nervous disorders; epileptiform fits; hyperirritability; ataxia; anemia; loss of appetite; edema; symmetrical dermatosis; dermal lesions; iron deposition in liver; rise in serum iron (6, 7).
Pantothenic acid	Clubbed gills (1, 2, 3, 4, 5). Prostration; loss of appetite; necrosis and scarring; cellular atrophy; gills covered with exudate; sluggishness; general mumpy appearance (4, 5).	Prostration; loss of appetite; necrosis and scarring; cellular atrophy; spectacle alopecia; generalized scaling and dermatitis; diarrhea; hyperemia of intestine; myelin degeneration of nerves (6, 7).
Inositol	Poor growth; distended stomach; increased gastric emptying time (1, 4). Degenerated fin (1).	Poor growth; increased gastric emptying time; alopecia; nutritional encephalomalacia (6, 7).
Biotin	Loss of appetite; poor growth (1, 2, 4). Blue slime patch disease (2). Dark coloration; muscle atrophy; spastic convulsions; fragmentation of erythrocytes (4).	Loss of appetite poor growth; muscle atrophy; Seborrheic skin disease; generalized erythema; spastic gait; necrosis of fibers; increased sarcolemma (6, 7).
Folic acid	Poor growth; anemia (1, 4). Lethargy; fragility of caudal fin; dark coloration (4).	Poor growth; lethargy interspersed with convulsions; megaloblastic erythropoesis; nutritional cytomenia; infarction of spleen (6, 7).
Choline	Poor growth; poor food conversion (1, 4). Hemorrhagic kidney and intestine (1). Aversion to food (4).	Poor growth; poor food conversion; aversion to food; fatty infiltration of liver: necrosis and scarring; reddish kidney; hemorrhagic eyes (6, 7).
Nicotinic acid	Loss of appetite; lesions in colon; jerky or difficult motion; weakness: edema of stomach and colon; muscle spasms while apparently resting (4). Swollen gills but not clubbed (1).	Loss of appetite; lesions in colon; jerky or spastic gait; weakness; pain; skin eruptions; edema of stomach and colon: anorexia; diarrhea; neurological lesions; fatty livers; vessel dilation (6, 7).

nin B_{12}	Poor appetite; erratic hemoglobin and erythrocyte counts; fragmentation of erythrocytes (4).	Pernicious anemia; macrocytic anemia; sprue; low or poor growth in young (6, 7).
ninobenzoic acid	Poor appetite; light colored livers (1). No abnormal indications in growth, appetite, mortality (4).	Alopecia in rats and poor growth in chick (6, 7).
rbic acid	Hemorrhagic liver, kidney, and intestine (1). No abnormal indication in growth, appetite, mortality (4).	Scurvy; capillary fragility; immature fibroblastic formation (6, 7).
d Liver Oil"	Necrotic kidney (1).	

bserved by McLaren *et al.*, (1947) in rainbow trout
bserved by Phillips *et al.*, (1945-1949) in rainbow, brook, and brown trout
bserved by Wolf (1951) in rainbow trout
bserved by Halver (1953) in chinook salmon
bserved by Rucker, Johnson, and Kavdas (1952) in chinook salmon
escribed in other animals by Hawk, Oser, and Summerson (1949)
escribed in other animals by Wooster and Blanck (1949)

inook salmon and other workers showed similar results when high choles- rol diets were fed to trout (Hewitt, 1937). Diets of high fat content or e lack of adequate exercise with normal or high food intake also caused estructive changes in the liver and pancreas (Hess, 1935). Choline proved n effective remedy for prevention of fatty degeneration of the liver and ancreas when the fat content of the diet components did not exceed 0 percent or 2 percent cholesteral (Donaldson, 1943).[2]

Studies on the absorption rate and utilization of carbohydrates in trout nowed that, although the fish could absorb large quantities within a short eriod, the blood sugar level rose appreciably which indicated that trout re not physiologically able to handle carbohydrates at the same rate as igher vertebrates (Phillips, Tunison, and Brockway, 1948). Hypergly- emia also occurred in sockeye salmon, *Oncorhynchus nerka,* but was effec- ively reduced to normal glucose levels by administering cattle insulin. ligh glycogen livers and degenerated pancreatic tissue were again observed vhen diets of high carbohydrate content were used and a tolerance level of 9 percent of the diet was suggested. Reason dictates a level of not more han 20 percent of fats and carbohydrates combined in salmonid diets.

Since salmonid fish are carnivorous, excessive protein levels in the diets probably could not be obtained except in the experimental laboratory. Protein or amino-acid levels cannot be included in this review since the amino-acid requirement of fishes is not yet established. The higher the protein content of the diet the greater is the growth, provided all other essential factors are present.

As in most phases of fish nutrition, the determination of requirements of the inorganic elements has not been completed. Only iodine and sodium chloride have been shown to be essential for growth and metabolism, but the exact role of physiologically active salts has not been defined for fish. The prevention of goiters in fish in some iodine-deficient areas by the use of iodine or iodine compounds was described previous to the period of this symposium. Under normal conditions, the inorganic components of the diet may be ignored for most diet ingredients contain sufficient amounts of physiologically active salts except in highly purified experimental diets or in waters of low inorganic salts. With the advent of experimental diets containing salt-free components and the possible use of new water-deionizing equipment, an entire new field of exploration of the specific role of the elements and their salts in enzyme kinetics and intermediary metabolism lies open.

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TUMORS AND OTHER ATYPICAL CELL GROWTHS IN TEMPERATE FRESHWATER FISHES OF NORTH AMERICA

Ross F. Nigrelli

New York Aquarium, New York Zoological Society
New York, New York

Abstract

This report deals with any abnormal tissue, the growth of which exceeds and is uncoordinated with that of the normal tissue. Included in this category are the neoplasia (benign and cancerous), non-functional hyperplasias, cellular hypertrophy as well as other atypical cell growths. The following topics are discussed with special reference to the temperate freshwater fishes of North America: papillomas, hyperplastic epidermal diseases (including fish pox), parasitic and neoplastic adenomas, carcinomas (incuding thyroid tumors), fibromas, fibrosarcomas, myxomas, leiomyomas, rhabdomyomas, granulomas, lymphosarcomas, pigment-cell tumors, neurofibromas, neurilemmonas, hamartomas, and teratomas.

The role of such factors as physical and chemical irritants, nutrition, endocrine dysfunction, heredity, embryonic disturbances, and such infectious agents as viruses, bacteria, mycotic organisms, and protozoans in the production of these abnormalities is given or suggested.

With the exception of certain tumors, our knowledge concerning neoplasms in fishes in general is extremely limited, and very few contributions have been made by American fishery biologists. It is suggested that a greater effort be made to recognize these diseases, especially tumors which appear spontaneously in large populations of fishes.

Introduction

The pathological conditions considered in this paper include any abnormal mass of tissue, the growth of which exceeds and is uncoordinated with that of normal tissue. Included are hyperplasias, neoplasias and other tumorous growths.

The term *hyperplasia* refers to an increase in the amount of cellular elements in a specific tissue in excess of those normally present. The epidermis of fishes is usually composed of relatively few layers of epithelial cells but under the action of certain stimuli may be increased many times (*e.g.*, in fish pox). We do not include hyperplasias which involve normal proliferation of cells as a compensatory response to loss of tissue or to increased functional demand, as the development of "pearl" organs in certain minnows during breeding season. We do include such proliferation, however, if the growth continues in an excessive manner after cessation of the stimulus, or if the stimulus persists so as to cause an exceptional amount of growth.

When the tissue retains its property of persistent growth independently of the stimulus which started it, the growth must be considered a *neoplasm*.

cording to Willis (1948), "The most distinctive character of neoplastic liferation is that it is uncoordinated, independent of the structural and nctional pattern of the organism, and indefinitely progressive. In this it fers fundamentally from reparative growth, hyperplastic growth and owth of malformation, in all of which the cellular multiplication is limit- in amount and duration in accordance with more or less specifiable ctors."

Neoplasias may also involve some permanent cellular changes. If the lls tend to revert to a more primitive and undifferentiated form, or if ere is a change in a cell by which it becomes incapable of attaining per- ct structure and function, then the growth is said to be an *anaplasia*. The ange of one kind of tissue into another, or the production of tissue by lls which normally produce tissue of another sort is called *metaplasia*. should be emphasized, however, that tumors of a given cell type may ary greatly in the degree of differentiation. In many thyroid tumors in shes there is little or no change from the normal histological pattern but nder certain conditions the follicles continue to proliferate, causing con- iderable destruction of the surrounding tissues.

The classification of tumors in fishes, as in other animals, is based on istogenesis. They are classified on the basic tissue of origin, such as pithelial, mesenchymal, hemopoietic, neural, . . . For a review of tumors n cold-blooded animals, the reader is referred to the excellent monograph y Schlumberger and Lucké (1948). Many of the tumors reported in the iterature have been analyzed and reclassified by these authors, and all the available information brought up to date. Their paper forms a basis for a better understanding of neoplasia in fishes. Table 1 lists the tumors reported in North American temperate fresh-water fishes. The tumors listed in Table 2 are found in European fresh-water fishes that are also indigenous to North America. The lists, however, do not include the hyperplasias and tumors caused by infectious agents which are also discussed in this paper. Table 3 is a list of North American fresh-water fishes in which lymphocystis disease (cell hypertrophy) has been reported.

The writer (Nigrelli, 1938) has previously reviewed some of the types of tumors and their probable causes in aquarium fishes. It is the purpose of this paper to discuss tumors and other atypical cell growths (*e.g.*, lymphocystis tumors) in temperate fresh-water fishes under both natural and captive conditions and to indicate, where possible, the importance of such factors as physical and chemical irritants, nutrition, endocrine dysfunction, heredity, embryonic disturbances, viruses, bacteria, mycotic organisms, and protozoans, in the production of these abnormalities.

TUMORS OF EPITHELIAL TISSUE

The benign epithelial tumors are referred to as papillomas and adenomas, whereas the malignant growths are called carcinomas. Terms such as epithelioma, epidermoid carcinoma and adenocarcinoma indicate variations of structure as to kind and degree of differentiation.

PAPILLOMAS

These vary in appearance from small, round, warty growths to large cauliflower-like masses. Histologically, the tumors show an extreme hyperplasia of the epidermis and the underlying (corial) connective tissue, with a typical papillary arrangement.

Although tumors of this type have been reported in a number of fresh-water fishes from Europe and other countries, only one case has been found in North America. Two large papillomas were described by Schlumberger and Lucké (1948) in the ventral part of the tail of an 8-year-old white sucker, *Catostomus commersoni,* caught in a Wisconsin lake.

It has been suggested that the occurrence of multiple wart-like papillomas in several fish of a population living in the same environment may be due to an infectious agent, and because of the presence of cellular inclusions in some of the growths, a virus has been suspected (see Nigrelli, 1952a). It is possible, however, that the tumors may be of traumatic origin. Thus, the writer observed the development of a fibro-epithelial papilloma in the snout of a rainbow trout, *Salmo gairdneri,* which was the site of a hemorrhagic lesion, the result of an injury caused by the fish bumping into the sides of the aquarium.

HYPERPLASTIC EPITHELIAL DISEASES

Many papillary-like growths in fishes are associated with various parasites and can only be distinguished from true neoplasias by histological and cytological examination. Some of these are discussed below.

Fish Pox (Hyperplastic Epidermal Disease).—Pox disease, sometimes called hyperplastic epidermal disease, cutaneous warts, or epithelioma papillosum, is characterized by numerous milky white or gray, flat, raised or papillary-like growths on the skin, fins, and eyes. Microscopically there is an exceptional amount of hyperplasia of the epidermis. According to Schlumberger and Lucké (1948), these growths cannot be sharply distinguished from true neoplasia, except that the lesions of pox usually regress and may eventually disappear.

Hyperplastic epidermal disease is common in carp, other cyprinids (tench, ides, and bream), pike, perch, and smelts. According to Plehn (1924), carp-pox was first recorded in 1563 by Gessner, the great naturalist of the 14th century. Since then, the disease has been reported in carp from all parts of Europe and Asia but to date it has not been found in North America in this species. The writer (1948b), however, has reported pox-like lesions in about 200 bluegills (*Lepomis macrochirus*) from Connecticut (Figs. 1 and 2). No doubt this disease must be much more widespread in North American fresh-water fishes.

In Europe, epidemics of fish pox often occur in large populations and, although the disease is not usually lethal, it makes the fish unsightly and therefore unmarketable. The lesions usually appear in the spring, persist during summer and fall, and gradually disappear in winter. Occasionally

growths may remain with little evidence of regression for at least 2
ars. This cycle, together with the recurrence of the disease in the same
species in the same lake, pond or stream from year to year, has led
ny European investigators to suspect an infectious agent. Although such
rasites as *Ichthyophthirius multifilis* (a holotrich ciliate), certain Myxo-
oridia, Microsporidia, argulids, and copepods can induce a mild hyper-
asia of the epidermis, the epidemiological, histological, and cytological
idence strongly suggests that a virus is the cause of fish pox (Nigrelli,
52b). The recent electron-microscopic studies by Roegner-Aust and
hleich (1951) and by Roegner-Aust (1953) demonstrating virus-like
rticles, measuring 70-220 millimicrons, in diseased cells and in particu-
tes of such cells tend to support the virus hypothesis for this disease.

The lack of critical evidence of a virus has led certain other European
vestigators to suggest that the disease may be the result of avitaminoses
calcium deficiency, or that it may be environmentally induced. Schäper-
aus (1941), who discussed these factors, believed that heredity plays the
ost important role in carp pox. There are some striking similarities be-
veen fish pox and the gill disease of trout described by Wolf (1945) in
hich a hyperplasia of the gill epithelium results from the combined action
f vitamin deficiency and chemical irritation.

Epidermal Hyperplasia Associated with Protozoan Parasites.—Hyper-
lasia of the epidermis may be caused by many parasites to which fish are
usceptible. The pustules seen in infections with *Ichthyophthirius multi-*
lis histologically show a simple hyperplasia of the epithelial cells around
he ciliate. The tissue is often thrown into papillary folds but little or no
onnective tissue is developed.

Tissue growths associated with Myxosporidia are more striking, some-
imes presenting tumors that are difficult to distinguish from true neoplasia.
Thus, Plehn (1924) described a tumor in a small *Leuciscus* sp. as a papil-
ary adenocytoma caused by *Myxobolus piriformis*. A papillary cystic dis-
ease affecting the barbels of brown bullhead, *Ameiurus nebulosus*, was
ound to be caused by the myxosporidian *Henneguya ameiurensis* (Nigrelli
and Smith, 1940). The parasites developed in the dermal connective tissue,
where they formed large cystic cavities. The epithelium overlying the cysts
was considerably thickened, giving the lesion a papillary or warty appearance. A tumor (Nigrelli, 1948a) in the snout of a redhorse sucker, *Moxostoma aureolum*, was found associated with the myxosporidian *Myxobolus moxostomi*. Histologically, the epidermis overlying the parasitic cysts was exceptionally hypertrophied and the hyperplasia consisted mainly of prickle cells.

Gill Disease (*Hyperplasia of Gill Epithelium*).—Gill disease is characterized by an extreme hyperplasia of the gill epithelium and sometimes by a fusion of adjacent lamellae through cellular proliferation. According to Plehn (1924), epidemics of this disease have been reported in Denmark, England, and Italy in Salmonidae, Clupeidae and Cyprinidae. The epidemiology is similar to that of fish pox, and this fact has led some investigators to suspect a similar etiology. Plehn, however, indicated that the condition is caused by abnormal chemical factors. This hypothesis is partly supporte by the experimental evidence obtained by Wolf (1945) for gill disease i hatchery-reared fingerling trout in New York State. Wolf, and others (Tunison, *et al*, 1944; Rucker, Harlan and Kaydas, 1952), have shown that fis placed on a pantothenic-acid-free diet developed the gill lesions ("clubbing") when treated fish were exposed to conditions in which metaboli fish wastes were more highly concentrated. According to Davis (1926 1927, 1953), similar lesions were found associated with some unknow species of myxobacteria in fingerling trout, largemouth bass, (*Micropteru salmoides*), smallmouth bass, (*M. dolomieui*), and blackcrappie, (*Pomoxi nigromaculatus*). Davis (1953) distinguished the two diseases with similar lesions as "bacterial gill disease" and "dietary gill disease."

Hyperplasia of the respiratory epithelium may also occur in respons to infection and infestation with animal parasites. Kudo (1919) describe such a growth in the gills of a channel catfish, *Ictalurus punctatus*, infected with the myxosporidian *Henneguya exilis*. The writer has note similar proliferation and fusion of respiratory elements in fishes infeste with ergasilid copepods, *Ichthyophthirius*, and/or with various species o monogenetic trematodes.

ADENOMA

This is a benign epithelial tumor with a gland-like structure. Only thre cases have been reported thus far in North American temperate freshwater fishes. Nigrelli (1943) reported an adenoma in the kidney of a northern pike, *Esox lucius*, which was associated with a lymphosarcoma. This neoplasm should be reclassified as a lymphadenoma since there was an extensive proliferation of the lymphoid elements as well as the uriniferous tubules. Adenomas of the ovary and kidney have been described by Biesele (1943) and by Schlumberger and Lucké (1948) in a goldfish *Carassius auratus*, and catfish, respectively. The catfish tumor occurred in a specimen which was also affected with an epidermoid carcinoma of the lips.

The writer recently received from Dr. S. F. Snieszko, U. S. Fish and Wildilfe Service, an enlarged liver (30 grams) taken from a female rainbow trout. The tumor was identified as a hepatoma (Fig. 3). The diseased fish liver was sent to Dr. Snieszko by Mr. Robert Piper, Newville, Pa. In the covering letter, Mr. Piper stated, "This morning we found another female rainbow trout and it had the swollen liver I described to you on my visit to Leetown." This would indicate that hepatomas, and possibly carcinomas, may be relatively common in this strain of rainbow trout. The relationship of parasites, haematochromatosis (haemosiderin), and cirrhosis to liver tumors should be investigated. These factors are often present in fish and may be regarded as predisposing conditions.

HYPERPLASIA OF EPITHELIAL ELEMENTS OF GLANDS AND OTHER ORGANS ASSOCIATED WITH PARASITES

It is well known that parasites can be the etiological agents in certain tumors of mammals and in other animals (Ewing, 1940; Craig and Faust, 1940; Willis, 1948). In coccidiosis of the liver of rabbits, the parasites

ite a tumor-like proliferation of the bile duct. As pointed out by Ewing,
process is strictly dependent upon the presence of the *Coccidia,* and the
nor regresses when the parasites are removed. Because it regresses, the
wth is not a true tumor. Nevertheless, it has some of the characteristics
a neoplasm, even though they are dependent on the parasitic irritant.
e same principle holds true for all tumors and hyperplasias in fishes
sed by parasites.

Information is limited concerning the exact pathological effects of fish
rasites. In the majority of fishes, the tissue reactions are indicated by
al accumulation of histiocytes (macrophages), granulocytes, plasma
lls, haemosiderin, and ceratoid elements. Atrophy, hyalin degeneration
d other necrobiotic changes are often present in the immediate regions
the infection. Frequently the host reaction to the parasites is manifested
mild inflammation, simple cyst formation, or by an extensive fibrosis,
rdering on a true fibroma. Occasionally, there may also be a decided
perplasia of the epithelial elements, often resembling cystadenoma, ade-
ma, and adenocarcinoma in parasitic infections in the liver, kidney,
nads, intestine, and gall and urinary bladder. Such growths are particu-
rly evident in gall-bladder infections by Myxosporidia (Kudo, 1919,
30; Fantham, and Richardson, 1940).

EPITHELIOMA—EPIDERMOID CARCINOMA

Epitheliomas differ from papillomas in that the epithelial cells tend to
vade the corium and other underlying structures of the skin, thus show-
g some degree of malignancy. Histologically, fish epitheliomas resemble
e mammalian epidermoid carcinomas in that they consist of pavement
pithelium which forms solid downward growths (pegs) from the basal
yer of the epidermis.

In Europe such tumors have been reported in carp and goldfish (Table
). McFarland (1901) was the first to report an epidermoid carcinoma in
North American fresh-water fish, the white catfish (*Ictalurus catus*).
ore recently, Lucké and Schlumberger (1941) and Schlumberger and
ucké (1948) described such tumors in the lips, oral mucosa, and dental
lates of 266 mature brown bullheads from the Delaware and Schuykill
ivers, in or near Philadelphia. The writer has two specimens with similar
ip tumors which were collected by Mr. Roland Smith, New Jersey Con-
ervation Department, from Strawbridge Pond (Burlington County) and
Lenape Lake (Atlantic County), both of which drain into the Delaware River (Fig. 4). The appearance of these tumors in a number of individuals of a single species from one general area (Delaware River and its drainage system) should lead one to suspect, environmental, hereditary, or infectious agents as the cause.

ADENOCARCINOMAS AND THYROID TUMORS

Carcinoma is a malignant growth of epithelial cells which tend to infiltrate the surrounding tissues and give rise to metastases. Adenocarcinoma is a malignant tumor of gland-cell origin. Tumors of the latter type are the predominant cancers in man.

With the exception of thyroid tumors, there is a dearth of informatio concerning adenocarcinomas in fishes. The only cases in fresh-water fishe were reported by Schmey (1911) and by Plehn (1924) in the kidney o the eel, *Anguilla anguilla*, by Haddow and Blake (1933) in the ovary o a northern pike, and by Nigrelli and Gordon (1951) in the pancreas of hybrid platyfish, *Platyoecilus maculatus* x *Xiphophorus helleri*. There i some question whether the ovarian tumor reported by Biesele (1943) i the goldfish, is an adenoma or adenocarcinoma. The same may hold tru for the hepatomas recorded in trout.

The writer recently received from Mr. Roland Smith, a 3-year-ol female carp (*Cyprinus carpio*), measuring 37.5 centimeters, with a massiv tumor of the stomach (Figs. 5 and 6). The growth was identified as a adenocarcinoma of hepatic origin. This is the second case of a stomac carcinoma. Previously, we have reported a carcinoma-like tumor in th stomach of a deep-sea fish (Nigrelli, 1947a).

It should be emphasized that the incidence of tumors of soft tissues an organs must be higher than indicated by the record. The lack of information is no doubt related to the fact that they usually present no external manifestations and are thus generally overlooked.

Thyroid tumors, however, are relatively common in fishes, especially in the salmonoids (see Tables 1 and 2). The only case of a thyroid tumor in a non-salmonoid temperate fresh-water fish previously reported was described by Marine and Lenhart (1910b) in a northern pike. The writer has in his possession photographs of a thyroid tumor in a goldfish (Fig. 7) which were taken by the late G. M. Smith, Yale University.

Several thousand cases of thyroid tumors in salmonoids have been reported since they were first described in 1883. Many of these growths represent simple hyperplasia (see Robertson and Chaney, 1953) and goiters but there can be no doubt that some of them are true adenomas and adenocarcinomas. The writer (1952a) has taken the view expressed by Willis (1948) with regard to human thyroid tumors, namely, that no clear separation of epithelial hyperplasia, benign and malignant thyroid tumors is possible. The gland in teleosts is a non-encapsulated structure which when unduly stimulated produces a progressive growth that is capable of infiltrating surrounding tissues, causing considerable destruction. Histologically, many such growths are of simple hyperplasia. In others, the picture may be somewhat similar to the interacinous adenomas in human goiters reported by Ewing (1940). In bony fishes, interacinous adenomas may represent a true neoplastic process even though there may be little change in the histological character of the tissue. Where anaplastic and metaplastic changes are evident, the thyroid tumors in such fishes must be considered as malignant adenocarcinomas.

As in human thyroid tumors, the exact cause of the growths in fishes has not been determined, even though some can be made to regress by the addition of iodine to the diet. Jaboulay (1908), Gaylord and Marsh (1914), and Nigrelli (1952a) have suggested that factors other than iodine deficiency in the diet may be responsible for thyroid tumors in ies. The studies of Gorbman and Gordan (1951) and by Berg, and rdon (1953) in Mexican killifishes indicate that heredity may play an portant role.

TUMORS OF NON-HEMOPOIETIC MESENCHYMAL TISSUES

The neoplasias included in this category arise in connective, skeletal, scular, meningeal, and muscular tissues. The benign tumors are called roma, myxoma, lipoma, chondroma, osteoma, angioma (haemangioma, nphangioma), meningioma, leiomyoma, and rhabdomyoma. Malignant mors are referred to as "sarcoma," often with a prefix corresponding to e benign counterpart, *e.g.*, fibrosarcoma.

Except for meningiomas, tumors of the above classes have been reported fishes. As stated by Schlumberger and Lucké (1948), "The inter- utability of mesenchymal tissues, and the complexity of tumors arising om these tissues, render their classification difficult." For this reason, any of the tumors in fishes have been designated simply as sarcomas nce the exact histogenesis has not been determined.

FIBROMAS, FIBROSARCOMAS, AND "SARCOMAS"

Fibromas are characterized by extensive proliferation of connective ssue. They are usually composed of collagenous fibers with the consis- ncy of the tumor (hard or soft) related to the degree of vascularity and lema, to the amount of chondrification and ossification, and to the ab- ence or presence of mucoid degeneration or cyst formation. The presence pleomorphic, closely packed cells embedded in a fibrillar substance is istinctive of fibrosarcoma.

Fibromas have been reported by various investigators in northern pike, arp, goldfish and lake trout (see Table 1 and 2). The tumors reported in e carp were found in the body cavity, whereas in other species, the umors were external, arising in the skin, subcutaneous tissue, and muscula- ure. The only cases of simple fibroma in North American temperate fresh- ater fishes were reported by Kreyberg (1937) in a brown trout, *Salmo rutta*, and by Nigrelli (1951) in a rainbow trout. An eastern chain ickerel, *Esox niger*, recently sent to the writer by Mr. Roland Smith, was ound to have a massive fibroma (approximately 2.5 centimeters in diam- ter) in the lower jaw (Fig. 8). Microscopically, the tumor was composed f dense figrous tissue arranged in whorls, and, although the growth was oorly vascularized, very little necrosis was evident.

Tumors for which the exact histogenesis could not be established but which contained pleomorphic sarcomatous-like elements and very little ibrous tissue were classified as "sarcomas" by Schlumberger and Lucké (1948). Of particular interest are the subcutaneous sarcomatous-like growths reported in goldfish by Roffo (1924), Montpellier and Dieuzeide (1932), and Lucké, Schlumberger, and Breedis (1948). Each author described tumors which appeared spontaneously in a number of fish kept n the same aquarium or pool, thus indicating an infectious process or

TABLE 1.—*Tumors in North American temperate freshwater fishes*

[Number after species indicates cases reported. Common names in this table conform to the Society's official list and are not necessarily the same as given by the original authors]

Type of tumor and species of fish	Site of tumor	Author
Papilloma		
White sucker (1)	Skin, near tail	Schlumberger, and Lucké, 1948
Fibro-epithelial papilloma		
Rainbow trout (1)	Snout	Nigrelli, this paper
Adenoma		
Brown bullhead (1)	Kidney	Schlumberger, and Lucké, 1948
Northern pike (1)	Lipsdo.	Nigrelli, 1943
Goldfish (1)	Ovary	Biesele, 1943
Rainbow trout (1)	Liver	Nigrelli, this paper
Epithelioma [1]		
White catfish (1)	Lips	McFarland, 1901
Brown bullhead (166)	Lips and mouth	Lucké, and Schlumberger, 1941
do. (100)	do.	Schlumberger, and Lucké, 1948
Adenocarcinoma		
Carp (1)	Stomach	Nigrelli, this paper
Thyroid tumors		
Salmonoid fishes (several thousands)		
Brown trout	Thyroid	Smith, 1909
Brook trout	do.	Marine, and Lenhart, 1910a, 1910b, 1911
Rainbow trout	do.	Marine, 1914
Sebago salmon	do.	Gaylord, and Marsh, 1914
Brown trout	do.	do.
Atlantic salmon	do.	do.
Lake trout	do.	do.
Pink salmon	do.	do.
Coho salmon	do.	do.
Chinook salmon	do.	do.
Sockeye salmon	do.	do.
Sunapee trout	do.	do.
Lake whitefish	do.	do.
Non-salmonoid fishes		
Northern pike (1)	do.	Marine, and Lenhart, 1910b
Goldfish (1)	do.	Nigrelli, this paper

Fibroma		
Brown trout (1)	Abdominal	Kreyberg, 1937
Rainbow trout (1)	Jaw	Nigrelli, 1951
Chain pickerel (1)	do.	Nigrelli, this paper
Sarcoma, unclassified [2]		
Goldfish (1)	Skin	Schamberg, and Lucké, 1922
do. (1)	Dorsal fin	Dominguez, 1928
do. (30)	Subcutaneous	Lucké, Schlumberger, and Breedis, 1948
Myxoma		
Brown trout (3)	Skin	Nigrelli, 1940
Rainbow trout (1)	do.	do.
Bluegill (2)	do.	do.
Largemouth bass (2)	do.	do.
Smallmouth bass (4)	do.	do.
Rock bass (1)	do.	Nigrelli, 1943
Goldfish (several)	do.	Schlumberger, and Lucké, 1948
Leiomyoma		
Goldfish (1)	Cutaneous	Nigrelli, this paper
Rhabdomyoma		
Cutthroat trout (1)	Trunk	Adami, 1908
Lymphosarcoma		
Northern pike (1)	Dorsal fin	Ohlmacher, 1898
Atlantic salmon (1)	Kidney	Haddow, and Blake, 1933
Northern pike (12)	do.	Nigrelli, 1947b
Muskellunge (1)	Trunk	Nigrelli, 1952b
Neurilemmona and neurofibroma		
Brook trout (25)	Mesentery and pancreas	Young, and Olafson, 1944
Brown trout (1)	do.	do.
Goldfish [3] (14)	Cutaneous	Schlumberger, 1949
do. (53)	Cutaneous, eyes, branchial and peritoneal cavities	Schlumberger, 1951, 1952
do. (2)	Cutaneous and eye	Nigrelli, this paper

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[1] Epidermoid carcinoma

[2] Fibrosarcoma

[3] Originally called leiomyoma

Table 2.—Tumors in European temperate freshwater fishes which also occur in North America

[Number after tumor type indicates cases. Common names in this table conform to the Society's official list and are not necessarily the same as given by the original authors]

Type of tumor	Site of tumor	Author
	Tumors in northern pike (*Esox lucius*)	
Adenocarcinoma (1)	Ovary	Haddow, and Blake, 1933
Fibroma [1] (1)	Muscle	Plehn, 1906
Sarcoma [2] (1)	Kidney	Plehn, 1909, 1924
Osteoma (1)	Jaw	Bland-Sutton, 1885
do. (1)	Vertebra	Plehn, 1906
Osteosarcoma (1)	Anal fin	Wahlgren, 1876
Lipoma (1)	Subcutaneous	Bergman, 1922
Lymphosarcoma (1)	Subcutaneous	Haddow, and Blake, 1933
	Tumors in carp (*Cyprinus carpio*)	
Epithelioma [3] (1)	Skin	Dauwe, and Pennemann, 1904
do. (1)	Not mentioned	Bashford, Murray, and Cramer, 1905
do. (1)	Fins and operculum	Fiebiger, 1909a
Fibroma (1)	Peritoneum	Crisp, 1854
do. (1)	do.	Gervais, 1876
do. (1)	Mesentery	Ronca, 1914
Osteochondroma (1)	Skull	Fiebiger, 1909b
	Tumors in goldfish (*Carassius* spp.)	
Papilloma (2)	Fins	Sagawa, 1925
Epithelioma (1)	Bladder	Plehn, 1909
Fibroma (1)	Orbit	Guglianetti, 1910
do.[4] (1)	Subcutaneous	Wago, 1922
do.[5] (1)	Skin	Sagawa, 1925
do. (1)	Trunk muscle	Eguichi, and Oota, 1926
Sarcoma, unclassified (1)	Dorsal fin	Bland-Sutton, 1885
do. (1)	Subcutaneous	Semer, 1888
do. (1)	do.	Johnstone, 1923
do. (7)	do.	Roffo, 1924
do. (5)	do.	Montpellier, and Dieuzeide, 1932
Neurofibroma (1)	Skin	Picchi, 1933
Lymphosarcoma	Kidney	Plehn, 1924

Tumors in trout and salmon (*Salmonidae*)

Papilloma, brow trout (1)	**Skin**	Thomas, 1932b
Adenoma		
Hepatoma, brown trout (1)	**Liver**	Plehn, 1909
do., rainbow trout (1)	do.	Haddow, and Blake, 1933
Cystadenoma, cutthroat trout (1)	Intestine	Thomas, 1931a
Dental plate tumor,[6] trout sp.? (1)	Dental plates	Plehn, 1912
Thyroid tumors, brown trout (3,000)	Thyroid	Bonnet, 1883
do., rainbow trout (3)	do.	Plehn, 1902
do., Atlantic salmon (1)	do.	Gilruth, 1902
do., trout spp. (several)	do.	do.
do.,[7] trout spp.	do.	Pick, 1905
do., trout spp. (6)	do.	Jaboulay, 1908
do., rainbow trout (many)	do.	Leger, 1925
do., trout sp. (1)	do.	Peyron, and Thomas, 1930
do., salmon sp. (1)	do.	do.
Fibroma, brown trout	Subcutaneous	Eberth, 1878
Sarcoma, unclassified, brook trout (1)	Trunk muscle	Plehn, 1906
do., chum salmon (1)	Body wall	Kazama, 1922
do., rainbow trout (1)	Not given	Leger, 1925
do., chum salmon (2)	Body wall	Takahashi, 1929
Do.,[8] pink salmon (1)	do.	do.
Leiomyoma, rainbow trout (1)	Stomach wall	Plehn, 1906
do., trout, *Salmo carpio?* (1)	Pylorus	Pesce, 1907
Osteoma, brook trout (1)	Fin rays	Thomas, 1932a
Erythrophoroma, trout sp. (1)	Skin	Thomas, 1931b

Tumors of threespine sticklebacks (*Gasterosteus aculeatus*)

Haemangioma (3)	Subcutaneous and head	Plehn, 1906
do. (1)	Iris	Johnstone, 1915

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[1] Lipofibroma
[2] Probably lymphosarcoma
[3] Epidermoid carcinoma
[4] Myxoma?
[5] Multiple tumors, maybe neurofibroma
[6] Epithelial origin
[7] American spp. sent to Pick
[8] May be a lymphosarcoma

presence of external carcinogenic factors. Lucké Schlumberger, and Bree reported 30 cases from pools in Atlantic City and in the Philadelphia Z A topographical analysis showed that most of the tumors occurred in t left lateral side of the body, the majority in the trunk region. Histolo cally, the growths were found in the corium and resembled fibromas, fib sarcomas, and occasionally myxomas, but because of the small amount fiber formation, a purely fibroblastic origin was considered doubtful. The investigators concluded that hereditary factors probably played no part the etiology of the disease but found some indirect evidence that t tumor-inducing factors were either transmissible or environmental. E posure of healthy fish to a presumably tumor-inducing environment l to the tentative conclusion that the carcinogenic factors were either wea or slow in their action.

FIBROSIS ASSOCIATED WITH PARASITES

Many fish parasites are capable of eliciting a connective-tissue respons The degree of proliferation depends upon the species of parasite and th intensity of the infection or infestation. Connective-tissue cyst formatic is a characteristic host response to larval nematodes, certain lernaeid cop pods, larval cestodes, and to the metacercaraial stage of many of th digenetic trematodes. The development of such cysts, however, is mo striking in certain types of myxosporidiosis, especially in infections of th subcutaneous tissues. Diffuse infections in this area often result in extensiv development of collagenous fibers, producing massive tumors resemblin true neoplasia (Nigrelli and Smith, 1938).

Nigrelli (1948a) suggested that intracellular and intercellular myxo sporidians elaborate enzymes (hyaluronidase) or other chemical sub stances that may be the stimuli responsible for cellular hypertrophy, hyper plasia, and even metaplasia often noted in these infections. The latte condition, which is characteristic of many malignant neoplasias, was ob served by Kudo (1929). He noted and described the transformation o subcutaneous connective tissue into "epithelioid" elements in areas of in fection with *Thelohanellus notatus* in the bluntnose minnow, *Hybor hynchus notatus*.

MYXOMATAS

These are tumors of loose connective tissue with branched cells interspersed with mucoid material. Certain mesenchymal tumors in goldfish reported by Lucké, Schlumberger, and Breedis (1948) were regarded as tumors of this type by Schlumberger and Luckè (1948). Nigrelli (1940, 1943) recorded 13 cases of myxomatas in six species of North American temperate fresh-water fishes (Table 1). In each instance, the growth was a grayish elevated, translucent patch in the dorso-lateral region of the body. Histologically, the growth consisted of stellate-shaped cells forming a loose network of tissue. Whether or not these growths are true neoplasms remains to be determined.

he history of the disease in the rock bass *Ambloplites rupestris*, may icate the origin of the myxomatous growths in these fishes. The rock s was heavily parasitized with *Chilodonella* (a holotrich ciliate) which sed an extensive production of mucus, nearly covering the entire surface he body. When the infection subsided, the translucent mucoid growth eloped.

CHONDROMAS AND OSTEOMAS

Tumors involving the skeletal structures have not been reported in rth American fresh-water fishes. Several cases of neoplasias of various rts of the endoskeleton, fins, jaws, opercula, and skull, have been deibed, however, in other fresh-water fishes. Thus, chondromas or enchonomas have been reported in the crucian carp, *Carassius carassius*, by uslow (1915; see Plehn, 1924), in the barbels, *Barbus fluviatilis*, by Surck (1917), in the elritze (*Phoxinus laevis*) by André (1927) and in the velfish, *Hemichromis bimaculatus* by Nigrelli and Gordon (1946). The mor in the jewelfish occurred in the operculum; the reader is referred to is paper for a detailed histological description of an osteochondroma in fish.

The writer (1943, 1951) recorded an osteoma in a rainbow trout but on reexamination the growth was found to be a simple exostosis, the relt of an injury to the lower jaw. Osteomas and osteosarcomas, however, ve been reported in several species of fresh-water fishes (Table 2).

Tumors of meristic skeletal structures are probably much more common freshwater fishes than has been suspected. Many tumors and other normal growths involving the vertebrae and their associated parts are no ubt overlooked. Thus, by intensive search, Takahashi (1929) found 102 ases of bone tumors in the haemal spines of the 6th-8th vertebrae in *agrus major*, a Pacific sparid. Whether or not these are true osteomas r normal hyperostosis in aging fish remains to be determined (Breder, 952).

LIPOMAS

Lipodystrophy occurs frequently in fishes, especially under hatchery and quarium conditions. Lipomas, however, are extremely rare. Schlumberger nd Lucké (1948) recorded only seven cases in the literature, one of which vas described by Bergman (1922) from the subcutaneous region in the runk of a northern pike which measured 60 centimeters in length. The umor mass weighed 160 grams and microscopically consisted mainly of ypical fat cells.

LEIOMYOMAS AND RHABDOMYOMAS

Neoplasms of the musculature are also rare in fishes. Leiomyomas or smooth-muscle tumors have been found in the stomach wall of an 8-yearold rainbow trout by Plehn (1906) and in another species of trout (*Salmo carpio?*) by Pesce (1907; see Thomas, 1931a). The cutaneous leiomyomas reported by Schlumberger (1949) in 3-4 percent of the goldfish populati from a pond in Ohio, are now considered as neurilemmomas with chara teristics of the Antoni type-A tissue (Schlumberger, 1952). Because of t complexity of mesenchymal tumors in fishes, it is difficult to determine t exact histogenesis of some of the growths of such an origin. The Anto type-A neurilemmomas are partly characterized by palisade arrangeme of the nuclei. It should be emphasized, however, that not all tissues sho ing this nuclear pattern should be classified as neural in origin since oth tumorous tissues may show a superficial palisading of nuclei. Such a cond tion was seen in two leiomyomas found in the subcutaneous tissue of ribbontail goldfish (Fig. 9) sent to the writer by the late Dr. Nels Gowanloch, Louisianua Conservation Department, who found the specim in a pool in New Orleans. Histologically, the tumor was composed of shee of tissue with closely packed fibrillar-like elements with deeply staini nuclei in which the shape (oval, flat, elongate) conformed to the outline the cells. There was some indication that the leiomyoma arose from th smooth-muscle layer of the small blood vessels in the corium.

The only tumor of striated muscle in a fish from North American wate was reported by Adami (1908). The growth occurred in the trunk musc lature of a cutthroat trout, *Salmo clarki*, and was specifically identified a giant-cell rhabdomyosarcoma.

HAEMANGIOMAS

These are benign neoplasms consisting of newly formed blood vessel No growths of this type have been recorded in North American fishes a though they have been described by Plehn (1906) and Johnstone (1915 as occurring comparatively frequently in European sticklebacks, *Gastero steus aculeatus*.

CELLULAR HYPERTROPHY

Cellular hypertrophy or cell enlargement appears to be a characteristi reaction in fishes to intracellular and intercellular myxosporidians an microsporidians and to viruses. Such atypical growths are included in thi part of the discussion because the cells (fibroblasts, osteoblasts, chondro blasts and polyblasts) are derived from non-hemopoietic mesenchymal tissues, and under certain conditions produce massive tumor-like lesions Classical examples of such growths are the well-known lymphocystis elements and the so-called *Glugea* "cysts", both of which are extremely enlarged and transformed cells, presumably resulting from the presence of the intracellular parasites.

Glugea CYSTS

One of the more striking examples of cellular hypertrophy in fishes was described by Weissenberg (1921) in European sticklebacks, *Gasterosteus aculeatus* and *G. pungitius*, infected with the microsporidian *Glugea anomala* (Class Sporozoa, Subclass Cnidosporidia). The schizont invades a nective tissue cell where it undergoes a series of divisions, terminating sporogony. During this development, the cell enlarges and becomes nsformed into a cyst having a thick hyalin membrane. These parasitic s occur in the connective tissue of the corium, cornea, intestine, liver, gonads. External cysts may occur in the head, trunk, fins, and bran- l chambers. In the skin, the infected cell, or Glugea "cysts," may de- op from an original size of 10-15 microns to a diameter of 2 to 4 milli- ers (Kudo, 1924).

imilar "cysts" were reported by Weissenberg (1911) in European lt, *Osmerus eperlanus*, infected with *Glugea hertwigi*. This microspori- n is also responsible for frequent epidemics in smelt, *Osmerus mordax*, North America (Fantham, Porter and Richardson, 1941; Haley, 1952).

LYMPHOCYSTIS DISEASE OR VIRAL LYMPHOCYSTIOSIS

Lymphocystiosis is an infectious but usually non-fatal disease of marine d fresh-water fishes in which the affected cells reach gigantic size. The tory of this interesting abnormality, first reported in European flounders 1874, has been outlined by Nigrelli and Smith (1939) and by Nigrelli 952b). Table 3 lists the species in which the disease has been reported North America. It will be noted that the condition is evidently common the Percidae and Centrarchidae. The incidence in walleye *Stizostedion treum*, and in black crappie and white crappie, *Pomoxis annularis*, is mparatively high in some localities, and the disease is, therefore, of some onomic importance. The growths found in the skin make the fish so sightly that affected individuals are culled and discarded by lake fisher- en.

The lesions are grayfish, flat, nodular or tumorous growths having a anular appearance. This appearance is due to the presence of numerous hite, spherical, or ovid bodies which may measure up to several milli- eters in diameter. In living fish these bodies, so-called lymphocystis cells, times may be seen to drop off like so many tapioca beads. In preserved ecimens, the cells are easily dislodged since they are not cemented to djacent cells or neighboring tissue.

Lymphocystis cells are supposedly enlarged fibroblasts, osteoblasts, chon- roblasts, or polyblasts (histiocytes). The transformed cells show a striking esemblance to eggs or ergasilid copepods which are usually present in rge numbers in the gills of fishes affected with this disease (Nigrelli, 950). At one time or another, lymphocystis cells have been considered to e fish eggs, sporozoan parasites, and eggs of metazoan parasites. The iseased cells occur primarily in the lymph spaces of the skin, but they also ave been reported in the spleen, gonads, heart, gills, and stomach. It has ever been established whether they represent metastasized elements or are ells which have developed *in situ*. The lymphocystis cell in the skin may e surrounded by lymphocytes, macrophages (histiocytes), melanophores, nd collagenous fibers. In certain fishes (*e.g.*, walleye), there may be a onsiderable proliferation of connective tissue, resulting in massive fibroma-

TABLE 3.—*Lymphocystis disease in North American temperate freshwater fishes*

[Number after species indicates number of fish unless otherwise designated. Common names in this table conform to the Society's official list and are not necessarily the same as given by the original authors]

Species of fish	Locality	Author
Walleye	Lake Minocqua, Wis.	Mavor, and Feinberg, 1918
do.	Lake Erie	Hyde, 1937
do. (60)	Lake Erie and Lake Huron	Weissenberg, 1939
do. (5 percent)	Saginaw Bay, Lake Huron	do.
do. (7)	Lake Erie	Bangham, and Hunter, 1939
do. (6)	Illinois	Nigrelli, 1943
do.	Rolling Stone Lake, Wis.	Bangham, 1946
do.	Upper Turtle and Teal Lake, Wis.	Fischthal, 1947
do.	Lake Oneido, N.Y.	Walker, 1947
Sauger	Lake Erie	Bangham, and Hunter, 1939
Orangespotted sunfish	New York Aquarium	Nigrelli, 1943
Pumpkinseed	Philadelphia Aquarium	Weissenberg, 1945
do.	New York Aquarium	Nigrelli, 1952b
Bluegill	Philadelphia Aquarium	Weissenberg, 1945
Green sunfish x bluebill hybrid	U. S. Fish and Wildlife Service, Dexter, N.M.	do.,
Longear sunfish	St. Francis River, Greenville, Mo.	
Largemouth bass	Half Moon Pond, St. Mary's, Ohio	do.
do.	Huron River, Wayne Co., Mich.	do.
do.	Schuykill River, Philadelphia, Pa.	do.
Spotted bass	Wheeler Reservoir, Ohio	do.
Yellow perch	Lake Erie	Walker, 1947
Black crappie	Illinois River	Weissenberg, 1945
do.	Schuykill River, Philadelphia, Pa.	do.
do.	Illinois River valley	Hansen, 1951
White crappie (1.4 percent)	Senachwine Lake, Ill.	do.,
do. (19.5 percent)	Lake Chatauqua	do.

tumors (Fig. 10). This pathological state is characteristic of a host tion to parasitic infection or infestation. Evidently, lymphocystis s are either parasitic elements or represent host cells in which the racter has been altered to such an extent that they behave as parasites as foreign bodies.

ytologically, each lymphocystis cell is enclosed in a thick hyalin capsule contains an enlarged nucleus with one or several nucleoli, and a sely granular or vacuolated cytoplasm with basophilic, Feulgen-positive usions. Sometimes the entire cytoplasm reacts to Feulgen much in same manner as the yolk of egg cells. Weissenberg (1939), and more ently Alexandrowicz (1951), traced the development of the inclusions m a single Guarneri-like body in the young lymphocystis cell. The insions were described as increasing in size concomitantly with the engement of the diseased cell. Eventually, the basophilic material develops o a perinuclear network. According to Weissenberg (1951a), who first posed the virus hypothesis for lymphocystiosis, the network contains niophilic granular structures which represent stages in the developntal cycle of the lymphocystis virus. The virus particles are believed to umulate in large numbers in the mature lymphocystis cells and to be erated when the tumor cells disintegrate in the water after extrusion after death of the fish. For an excellent description and interpretation of histological and cytological features of the lymphocystis cell in various ges of development, the reader is referred to the paper by Alexanowicz (1951).

In temperate fresh-water fishes, lymphocystis disease usually appears in e spring, reaches a maximum development during summer and gradu-y disappears in fall and winter. The lesions, however, may appear and sappear suddenly (within a few days) or may persist for a year or more. he fact that not all fish of a species in one population are susceptible ring epidemics indicates that at least some individuals are resistant or e immune, probably as a result of a previous infection.

Successful intraspecific, interspecific and interordinal transmission of the sease was accomplished by Rasin (1927, 1928), Weissenberg (1939, 945, 1951a, b) and by Nigrelli (1952b). These investigators reported at healthy intact and bruised fish become infected after exposure to ater containing an emulsion of lymphocystis material, after intraperioneal and intradermal injection of emulsified preparations, after expore to water containing the filtrate of lymphocystis material, and after ansplantation of bits of lymphocystis tumor tissue. For the first time in e long history of lymphocystiosis, the filterability of the lymphocystis irus was demonstrated by Weissenberg (1951c). He reported a positive terordinal transmission from walleye to killifish, *Fundulus heteroclitus*, ith material filtered through a Chamberland-Pasteur filter L-5.

TUMORS OF HEMOPOIETIC TISSUES LYMPHOSARCOMAS

In the classification of human tumors, such neoplasias as lymphosarcomas, lymphatic leukemias, and Hodgkin's disease are considered as growths arising from hemopoietic tissues. No cases of leukemia or tun resembling Hodgkin's disease have been described in fishes. A number papers on lymphosarcomas, however, have been published and this subj was reviewed by the writer (Nigrelli, 1947b, 1952b).

Enough evidence has been accumulated to indicate that lymphosarcon may be widespread in the Esocidae during certain seasons of the year a that the disease may be infectious, probably caused by a virus or ricke sial-like organism. In the northern pike, the tumors were found in hemopoietic tissue of the kidneys and metastatic lesions were observed the liver and spleen. The origin of the cutaneous "lymphosarcomas" the muskellunge, *Esox masquinongy*, (Fig. 11) remains to be determin Fish often respond to cutaneous infections by an influx of large numb of histiocytes (macrophages or polyblasts). It is possible that under c tain conditions a hyperplasia of these elements may occur, producing histiocytoma or a growth which would have the appearance of a roun cell sarcoma or a lymphosarcoma. It would be biologically and onc logically important to determine the exact histogenesis, incidence, a transmissibility of this disease in the Esocidae and related species.

GRANULOMAS

Granuloma is a tumor which may result from bacterial, fungal, prot zoan, and other parasites. It is most frequently associated with myco infections, where granulation tissue, consisting of plasma cells, leucocyt giant cells, and fibroblasts, form a nodule around either the enti mycelium or a single hypha. The growths may become malignant if fibrosarcomatous-like tumor develops. The literature relating to this su ject in fish was reviewed by Ermin (1952) who also described in detail granuloma in a Turkish species. The only known instance of such a grow in a North American fresh-water form is the mycetoma reported by Walk (1951) in the head of a single fingerling landlocked salmon from an Ida hatchery. The granuloma was a large, lobed, clearly defined growth whi extended from the dorso-lateral skin to the midline both above and belo the brain. The septate mycelium formed centers of whorls or granulom The latter was composed mainly of fibroblastic cells and some epithelio or multinucleated giant cells. The growth involved the skin, periosteur and the membranes of the brain. Tumors of this kind are no doubt mo common than indicated by this single case.

TUMORS OF NEUTRAL TISSUES

Tumors of neural origin have been reported as neurofibromas, neurilem momas and neurogangliomas. Neurofibroma is a connective-tissue tum of the nerve-fiber fascicule, originating by proliferation of the perineuriu and endoneurium; neurilemmoma, also called Schwannoma and neurinom is a tumor of the nerve sheath (neurilemma); neuroganglioma (neuroma) which is rare in fishes, is a tumor of the nerve cell proper.

Neurofibroma and neurilemmonas appear to be relatively common i

ain fishes. There is some doubt that the neurilemmomas reported by
ing and Olafson (1944) in brook trout, *Salvelinus fontinalis*, from a
v York hatchery are true neoplasias. The leiomyomas in the skin of
ldfish described by Schlumberger (1949) have been reclassified as
rilemmomas by him (1952). This investigator (Schumberger, 1951,
2) reported neurilemmomas and neurofibromas in a relatively large
nber of goldfish and suggested that they are probably hereditary. A
vey (Schlumberger, 1952) of goldfish in a lagoon in Cleveland showed
t 8 to 10 percent of the fish had one or more tumors. Both sexes were
resented and fish were estimated to be between 5 and 8 years old. The
idence did not change in 6 years of observation. Furthermore, the record
wed that no goldfish were introduced to the lagoon since it was orig-
lly stocked in 1926. With the exception of one fish with an intra-
lominal and another with a branchial neurilemmoma, the tumors were
lely distributed over the surface of the body. One hundred and forty-
r tumors were found in 53 fish and seven cases were histologically
lignant. The assumption that the tumor were probably hereditary is
tly based on the fact that both tumor-bearing and otherwise normal
ı were often affected with anomalies that included polycystic kidneys,
atoconus, and buphthalmos. Schlumberger (1952) stated "The fre-
ency of congenital lesions served to emphasize the fact that the fish
re an isolated population probably subjected to considerable inbreeding
d therefore had some genetic homogeneity." He further suggested that
se tumors show a striking comparison with von Recklinghausen's neuro-
romatosis in man for which a hereditary factor has also been suggested.

Tumors of neural-tissue origin are no doubt common in goldfish through-
t the world. Some of those reported as fibromas and fibrosarcomas may
l into this category. The writer has in his possession two goldfish, one
m a pool in the San Diego Zoo and another from Atlantic City, with
urofibromas involving the trunk, operculum, and eye (Fig. 12). These
amples would suggest that such tumors occur in this species from other
rts of the United States. An intensive search would probably give a more
curate figure on the incidence.

TUMORS OF PIGMENT CELLS

The pigment cells in fishes are melanophores, xanthophores, and erythro-
ıores (allophores). Together with the non-pigmented elements, guano-
ıores and iridiocytes, such cells make up the pigmentary system in these
imals. Tumors composed of these cells that have been described in
hes are termed melanomas, xanthophoromas, guanophoromas, and
idiocytomas. Melanomas of the skin of fishes are the most common type
ıd also the most malignant of the pigment-cell neoplasia. Iridiocytomas
e the rarest.[1]

Pigment-cell tumors, especially melanomas have been reported more

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Through personal correspondence with Dr. E. S. Schmidt of the Biologisches Forschungsin-
tut at Hamburg, Germany, the writer has been made aware of an apparently malignant,
ansplantable iridiocytoma in certain albino strains of Siamese fighting fish, *Betta splendens*.

often in marine fishes than in fresh-water species (Nigrelli and Gordo 1944; Schlumberger and Lucké, 1948). For fresh-water species, the studi on hereditary melanomas in xiphophorine fishes and their hybrids by Go don (1951) are outstanding. These fishes are also susceptible to tumo involving the xanthophores, erythrophores, mixed pigment cells (xanth erythrophores), and combination of these with melanomas (Nigrel Jakowska, and Gordon, 1951).

Thomas (1931b) recorded the only pigment-cell tumor in a tempera freshwater fish—an erythrophoroma in the skin of an unnamed species European trout. The growth was orange and had infiltrated the anal fin. similarly colored tumor mass in the peritoneal wall of the stomach w suspected as a metastatic lesion.

The black tumors reported by Osburn (1925) in brown bullheads from lake in Falmouth, Massachusetts, may or may not be melanomas. The growths, which also have been observed by Vinal Edwards and Hen David Thoreau in brown bullheads from this locality and in the Conco and Assobet Rivers, were found in various parts of the skin and fins and the lips, mouth, esophagus, and gills. Because of the presence of numero bacteria, these lesions are not considered as neoplastic. Examination Osburn's Figures 5 and 6, however, shows a highly thickened corium ar somewhat hypertrophied epithelium. His Figure 6 is characteristic of ce tain melanomas observed by the writer in other fishes. It is possible tha these tumors in the catfish may be melanotic and that the bacteria may b secondary invaders. Further studies are needed to determine the exa nature of these apparently common tumors in catfish from the abov localities.

HAMARTOMAS AND TERATOMAS

Hamartomas are non-neoplastic tumors or tumor-like nodules whic arise as the result of embryological defects. They are abnormal formation of tissues and may replace or displace the normal structure. Thus, Schlumberger and Lucké (1948) referred to the tumor of the pineal organ in th mackerel, *Scomber scomber*, reported by Charlton (1929) as a hamartoma Charlton found that the area in which the pineal body should have bee located was occupied by a series of epithelial folds. In several places, bead like masses of hyalin cartilage were found in the abnormal tissue. Thi author considered the growth as a chondro-epithelioma. The tumor destroyed or replaced the pineal body but had caused little damage to th rest of the brain.

Teratomas, on the other hand, are true tumors or neoplasias characterized by the presence of embryonic remains of another individual. The condition reflects some degree of uncoordinated growth. Teratomas do no include, however, such abnormalities as fully formed, sometimes functional, supernumerary structures (*e.g.*, fins, gills, . . .). An extensive bibliography on teratology of fishes was given by Gemmill (1912) who also described and illustrated a large number of such abnormalities in trout an salmon, some of which may be true teratomas.

amartomas and teratomas are included in this discussion because ery biologists are well aware of some of the gross manifestations of these pical growths, especially since they commonly occur in hatchery fishes. dies relating to this subject in fishes have been neglected in recent rs by biologists and oncologists.

Need for Research on Tumors and Other Growths

t is apparent from this report that little is known about tumors and er atypical cell growths in temperate fresh-water fishes of North ierica. Excluding the salmonoid fishes with abnormal thyroid growths, y 17 species have been thus far recorded with neoplasias. No doubt the idence and number of species with tumors is much higher. That fish h abnormal growths are just as common as one might expect them to in a given population of a fresh-water species is indicated by the studies Lucké and Schlumberger (1941) and Schlumberger and Lucké (1948) o, with the aid of fishery biologists from Pennsylvania, obtained 266 own bullheads with lip cancers from the Delaware River drainage sys- n. One hundred and sixty-six were found in only 2 years. It would be luable for cancer specialists to determine whether such tumorous catfish cur in other parts of North America. This information would indicate iether or not the carcinogenic factors for this neoplasm are limited to e northeastern United States.

Two other diseases that should be studied more intensively, partly be- use a virus is suspected, are fish pox (hyperplastic epidermal disease) d lymphosarcoma. From casual conversations with fishery biologists it is e writer's impression that fish pox has been observed in species other an the bluegill from Connecticut (Nigrelli, 1948b). It is surprising that is disease has not been found in carp in North America, since epidemics carp pox have occurred in Europe and Asia since the Middle Ages. The ports of lymphosarcomas in North American and European Esocidae by hlmacher (1898), Haddow and Blake (1933), and Nigrelli (1947b, 52b) show that this neoplastia is also of common occurrence. Lympho- rcomas in early stages of development are probably overlooked since they ay arise in the kidney, an important lymphopoietic organ in teleosts. nly by careful examination of this and other lymphoid tissues (thymus, leen, intestinal mucosa) can the true incidence of this disease be de- rmined.

The relatively high incidence of epidermoid carcinomas in the lips of ullheads (Lucké and Schlumberger, 1941; Schlumberger and Lucké, 948) and the numerous cutaneous tumors of mesenchymal and neural rigin in goldfish (Lucké, Schlumberger, and Breedis, 1948; Schlumberger, 951, 1952) would lead one to suspect that the cause may be infectious, en- ironmental or hereditary.

The dearth of information on tumors in temperate fresh-water fishes of orth America can be partly attributed to the lack of interest by fishery iologists, especially among those in charge of lake and stream surveys, ho fail to forward diseased specimens to interested pathologists Since the writer's appeal to those attending this symposium in Malwaukee, a nu ber of fishes with important neoplasms have been received from vario parts of the country. Among them was a stomach carcinoma in a ca and a hepatoma in a hatchery-reared rainbow trout. These are record for the first time in this paper. It is our prediction that a more intensi search will reveal that the incidence of the two types of cancers in ea of these species will be relatively high.

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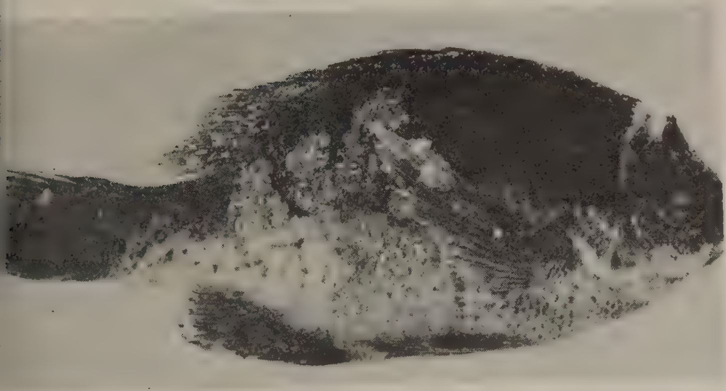


FIGURE 1.—Bluegill with hyperplastic epidermal disease, also called fish pox.

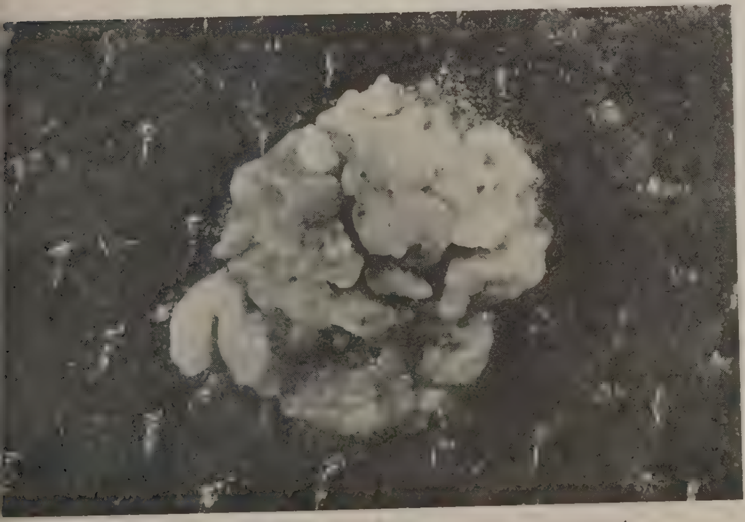


FIGURE 2.—Bluegill pox lesion showing papillary arrangement.

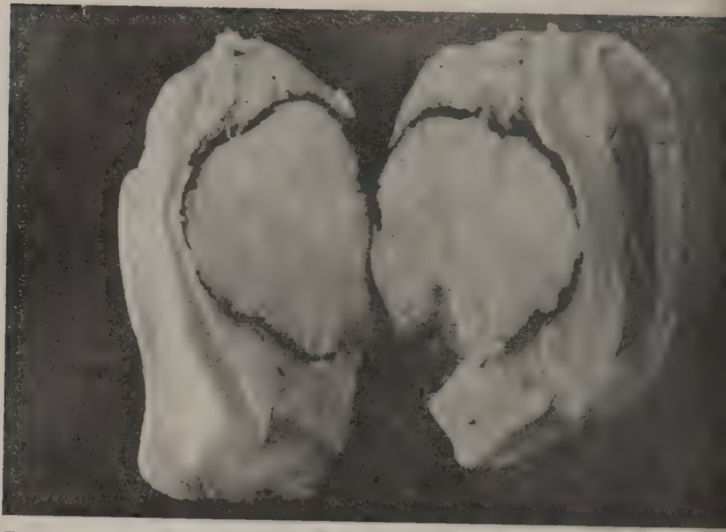


FIGURE 3.—Liver tumor (hepatoma) in rainbow trout. Submitted by Dr. S. Snieszko, U. S. Fish and Wildlife Service.

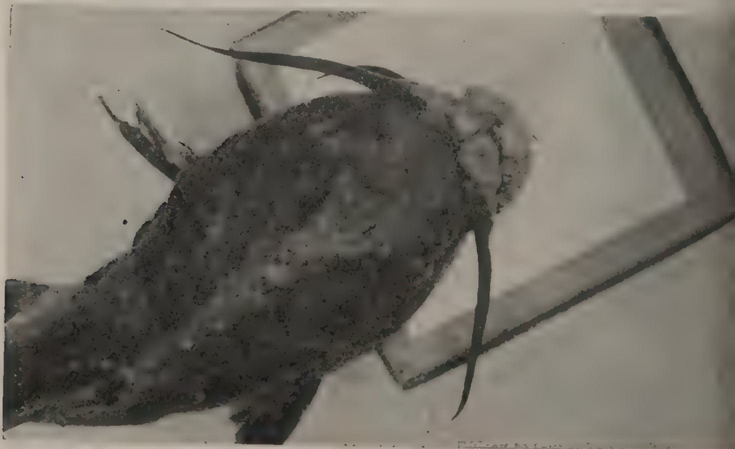
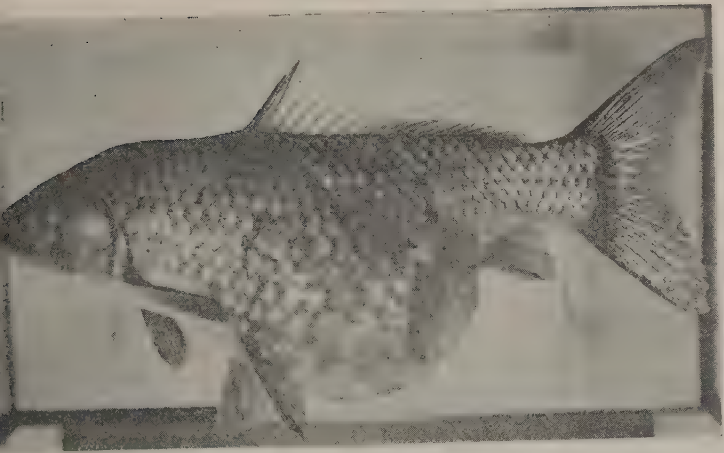


FIGURE 4.—Epithelioma (epidermoid carcinoma) in lips of brown bullhead. Submitted by Mr. Roland Smith, New Jersey State Conservation Department.



GURE 5.—Female carp showing external manifestation of stomach tumor. Photograph by Roland Smith.

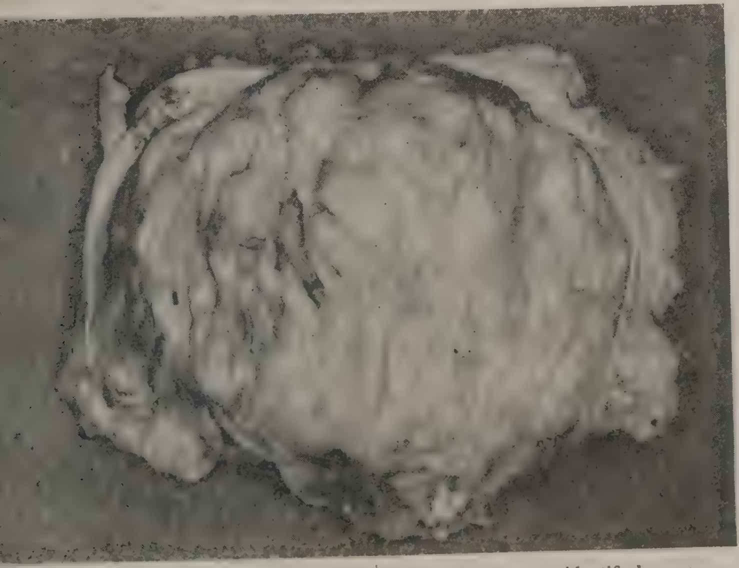


FIGURE 6.—Stomach mass, weighing 250 grams, which was identified as an adenocarcinoma of hepatic origin.

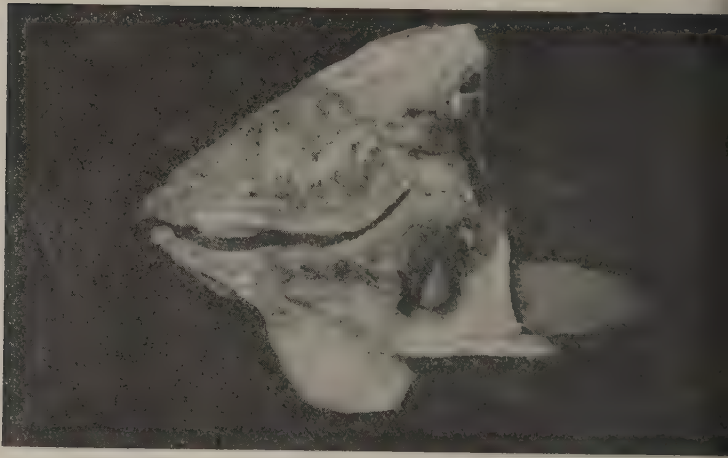


FIGURE 7.—Sagittal section through head of goldfish with thyroid tumor. Photograp by the late Dr. G. M. Smith, Yale Medical School.

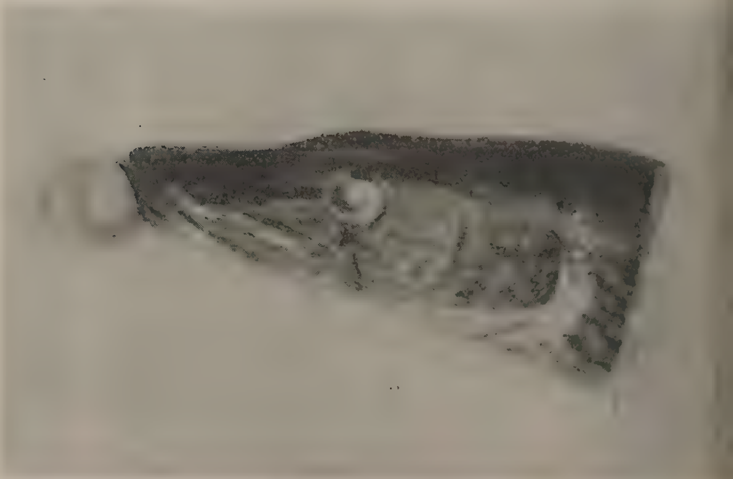


FIGURE 8.—Fibroma in lip of chain pickerel. Submitted by Roland Smith

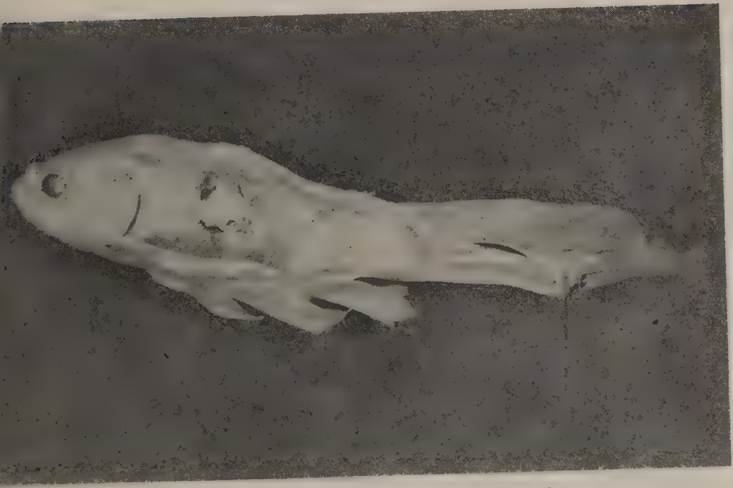


FIGURE 9.—Leiomyoma in ribbontail goldfish.

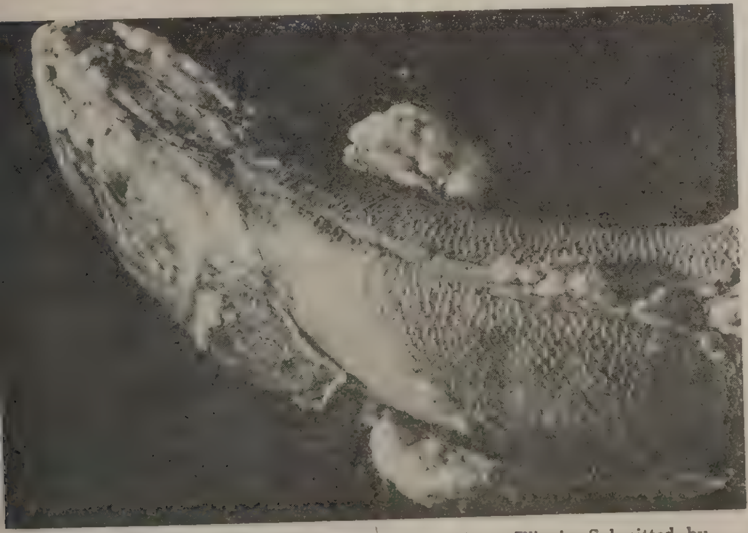


FIGURE 10.—Lymphocystis tumors in walleye from Illinois. Submitted by Dr. Louis A. Krumholz.

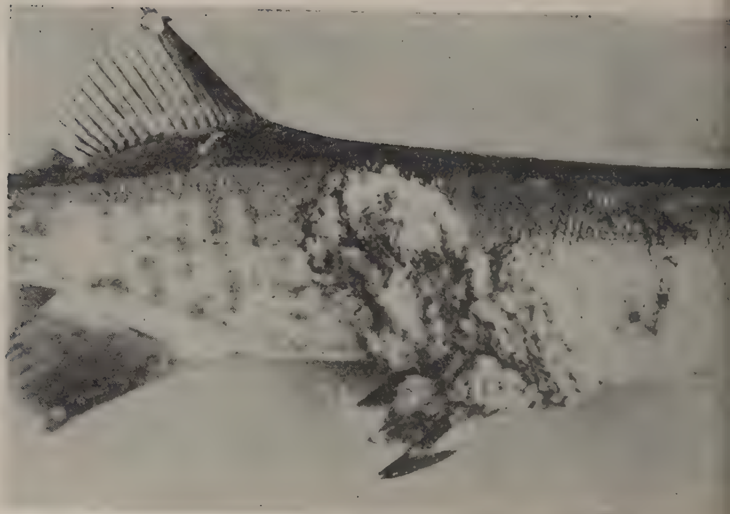


FIGURE 11.—Lymphosarcoma-like mass in region of pelvic fins in a muskellung Material and photograph by Dr. A. M. Fallis, Ontario Research Foundation.

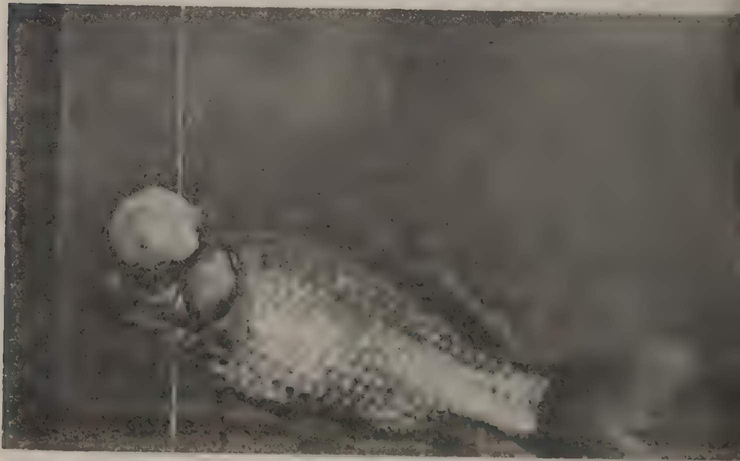


FIGURE 12.—Neurofibroma in goldfish. Photograph by Mr. S. C. Dunton, New York Zoological Society.

INFECTIOUS DISEASES OF PACIFIC SALMON

ROBERT R. RUCKER

U. S. Department of the Interior, Fish and Wildlife Service
Seattle, Washington

BRIAN J. EARP

Washington State Department of Fisheries
Seattle, Washington

AND

ERLING J. ORDAL

Department of Microbiology and Oceanographic Laboratories
University of Washington, Seattle, Washington

ABSTRACT

Investigations on infectious diseases of Pacific salmon due to micro-organisms other than viruses are reviewed. The etiological agents include trematodes, fungi, protozoa and bacteria. Bacteria have been found to be the most important agents of disease in the several species of Pacific salmon. Kidney disease, due to a small, unnamed Gram-positive diplobacillus, causes serious mortalities in young salmon reared in hatcheries. The disease has also been found in wild fish. Aquatic myxobacteria are important agents of disease both in the hatchery and in the natural habitat. One of the myxobacteria, *Chondrococcus columnaris*, causes disease at relatively high water temperatures. The problem of the taxonomy of this organism is discussed. Another myxobacterium, *Cytophaga psychrophila*, has been found responsible for epizootics in coho salmon at lower water temperatures, *i.e.*, in the range of 40° to 55° F. In outbreaks of gill disease in young salmon, myxobacteria of several kinds have been implicated.

A variety of bacteria has been found responsible for outbreaks of disease in salmon in sea water. The most important of these is a species of *Vibrio*. Tuberculosis has been found in adult chinook salmon and the evidence indicates that the disease was contracted at sea.

INTRODUCTION

Five species of salmon occur in the waters of the Northeast Pacific ocean. These salmon are distinct from the Atlantic salmon and from true rout, although they are included with these in the family Salmonidae. The Pacific salmon are anadromous fish and all belong to the genus *Oncorhynchus*. The names of the five species are chinook (*O. tshawytscha*), coho (*O. kisutch*), sockeye (*O. nerka*), chum (*O. keta*), and pink salmon (*O. gorbuscha*). The eggs develop in fresh water and the young remain there for periods ranging from a short time to a year or two before going to sea. After a year or more in salt water, the adult salmon return to fresh water to spawn. Consequently, it is logical to expect that there may be differen infectious agents which attack salmon in the two habitats. Furthermore, might be expected that the diseases of salmon in the fresh-water habita might be transmissible to other salmonid fishes. In general, this has prove to be the case. A good deal of attention has been paid to infectious disease of salmon in fresh water. So far, much less has been done in the study c diseases of salmon in the marine habitat; greater difficulties are inherent i the study of these diseases and the investigations carried out have bee largely exploratory in character.

The infectious agents responsible for mortalities in salmon in fresh wate include trematodes, protozoa, fungi, bacteria, and viruses. Viruses are considered in another paper in this symposium, hence no references will b made to them here.

TREMATODE PARASITES

Trematodes are of little consequence as a cause of fatal disease in salmo in the Pacific Northwest. The monogenetic trematode, *Gyrodactylus* sp. occurs occasionally in hatcheries but is easily controlled by treatment wit formalin. The metacercarial stage of the fluke, *Troglotrema salmincola,* i occasionally found in considerable numbers in salmon in areas where th snail, *Goniobasis plicifera,* is found. Bennington[1] has expressed the opinio that heavy infestations of the metacercariae can cause death of youn salmon. The fluke, *T. salmincola,* is generally considered responsible for th transmission of the etiological agent of salmon disease in dogs. This agen has been classified among the Rickettsia by Cordy and Gorham (1950) There is a possible relationship between the etiologic agent responsible fo salmon poisoning in dogs and that responsible for kidney disease in youn salmon (Earp, Ellis and Ordal, 1953).

PROTOZOAN PARASITES

The external protozoan parasites, *Costia, Trichodina,* and *Ichthyophthirius* are responsible for low grade infections and may cause mild epizootics in young salmon in hatcheries. This type of infection is characterize by the fish flashing and darting about, and the fish may show an increase in mucus secretion, or in the case of *Ichthyophthirius* show small white spots in the skin. These diseases are of little consequence in that they are readily controlled by formalin treatment, although *Ichthyophthirius* may cause some difficulty as it has a stage imbedded in the skin of the fish.

A stalked ciliate which has not yet been classified has been associated with some mortalities in young salmon. This protozoan was not affected by formalin in the concentrations normally employed, but was easily controlled by the use of acetic acid or pyridylmercuric acetate (Burrows and Palmer, 1949). Since prophylaxis with pyridylmercuric acetate is used routinely for gill disease, the parasite no longer presents a problem.

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[1] Bennington, Elwin Everett 1951. The life history of the salmon poisoning fluke *Troglotrema salmincola* (Chapin). 50 pp. PhD. thesis, Oregon State College.

The intestinal flagellate, *Octomitus salmonis*, occurs occasionally in stocks fish, but it is difficult to decide that it is actually a serious cause of mor- ties. Following standard practice, calomel is often used as the therapeutic ent in outbreaks of octomitiasis, but in our experience, it is difficult to nclude that the therapy is of any particular value. Unless other agents present, the losses presumably due to octomitiasis resolve in time even thout treatment.

Myxosporidia have been observed in salmon but no severe epizootics ve been recorded. A member of the genus, *Ceratomyxa*, was found in inbow trout from Lacamas Lake in Washington.[2] The legal sized fish veloped severe infections by this myxosporidian about six weeks after they d been planted in the lake. Similar fish held at the hatchery and those anted in other lakes did not develop this infection. Very large numbers of e rainbow trout were found dead and dying in the lake and were found be infested with tremendous numbers of *Ceratomyxa* sp. in the liver, leen, kidney and intestine. A catfish taken at the same time had a large runcle containing huge numbers of similar myxosporidia, but none were oted in the internal organs. It was reported by M. Smith[3] that a con- derable mortality had occurred earlier in the catfish present in the lake, but icroscopic observations were not made. It is possible that the surviving tfish present in the lake served as a source of the myxosporidia responsible r the mortality in the rainbow trout. Noble (1950) reported that a yxosporidium, *Ceratomyxa shasta*, was responsible for high mortalities in ainbow trout at the Crystal Lake hatchery in California. Possibly organ- sms of this type are more prevalent than has heretofore been realized, and hey may well be responsible for fatal disease in salmon.

PARASITIC FUNGI

An interesting micro-organism has been isolated from a serious outbreak f disease in trout, but it is also pathogenic to salmon under experimental onditions (Rucker and Gustafson, 1953). This organism generally occurs s a sphere varying from 10 microns to 80 microns in diameter, affecting ll organs and tissues of the fish. The organism has been identified as a pecies of *Ichthyosporidium*, although differing from previously described pecies. Morphologically it most closely resembles *I. hoferi*, which has been eld responsible for a disease in herring in sea water (Scattergood, 1948).

Saprolegnia parasitica is the commonest of the pathogenic or parasitic fungi in fishes. Infections with this fungus can be expected whenever fish are debilitated from other causes. Our experience is that any extensive out-break of *Saprolegnia* is a sequel to debilitation from some other infection and occasionally follows the use of an inadequate diet.

An unnamed fungus, temporarily classified in the order Sphaeropsidales of the Fungi Imperfecti, has been found responsible for disease in salmon.[4] This fungus was found in the extreme posterior part of the intestine of pink, sockeye and chinook salmon fingerlings. The populations of fish observed with this infection had just started feeding but still had considerable yolk material present. Necrosis of the posterior gut and musculature was associated with this infection. Outbreaks of this disease have not been widespread in character; but when it has occurred, the populations of fish affected suffered catastrophic mortalities.

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[2] Rucker, R. R., D. Lavere and E. J. Ordal. Unpublished data.

[3] Personal communication.

[4] Rucker, R. R. Unpublished data.

BACTERIAL DISEASES

A large share of our attention has been given to the study of bacterial diseases of salmon. Outbreaks of furunculosis, caused by *Bacterium salmonicida,* occur occasionally in stocks of young salmon. Though there have been reports of the occurrence of disastrous losses due to furunculosis in the past years, we have never observed such an outbreak. The disease in salmon responds readily to sulfamerazine or sulfamethazine. Apparently the disease in salmon is often self-limiting, for in a number of instances the disease has disappeared from control ponds which were not given sulfonamide therapy.

A variety of pseudomonads have been isolated during the course of outbreaks of disease in young salmon. *Pseudomonas fluorescens* or related varieties are most often found. Strains of *P. hydrophila* have been found, but less frequently. Although the pseudomonads isolated usually kill fish upon injection, they have never been found as primary agents responsible for an epizootic in salmon. The evidence indicates that pseudomonads should be included among the agents responsible for mortalities in young salmon debilitated from other causes. In one outbreak of disease in sockeye salmon fingerlings, a streptomycete and a concomitant pseudomonad were isolated from a number of moribund fish (Rucker, 1949). The organism was named *Streptomyces salmonicida* and was shown to be pathogenic. On inoculation characteristic necrosis occurred. This is interesting since no type of actinomycosis had previously been reported in fish. The pseudomonad was also pathogenic and when injected experimentally into fish caused peritonitis and the development of small areas of erythema on the surfaces of the fish.

External ulcers occur in some outbreaks of disease in young salmon, and in our experience, myxobacteria are characteristically involved. In no case has *Hemophilus piscium* been isolated, although the methods recommended by Snieszko, Griffin and Friddle (1950) and Snieszko (1952) have been used. *H. piscium* was originally isolated by Snieszko and Friddle (1950) and shown to be the etiological agent of ulcer disease in trout.

One of the most serious diseases in young salmon is "kidney disease." During recent years there have been increasing numbers of outbreaks of this disease in chinook, sockeye and coho salmon (Earp, Ellis and Ordal, 1953). The disease is a generalized infection and is usually characterized by the presence of definite lesions of the internal organs, especially the kidneys. Large numbers of very small Gram-positive diplo-bacilli are always found in the lesions. On gross examination, the kidney is by far the organ most frequently affected, and because of the frequency with which characteristic icroscopic lesions appear on this organ, the disease is commonly referred as kidney disease. In advanced stages of the disease petechiae are fre-ently observed. In many cases, following damage to the kidney, there is effusion into the peritoneal cavity. The fluid, often under pressure, con-ns large numbers of cells and the characteristic Gram-positive diplo-cilli.

Kidney disease occurs over a wide range of water temperatures. Many tbreaks have begun during the autumn months during periods of declin-g water temperatures. Under these conditions the mortalities gradually it inevitably increase, exacting a serious toll from stocks of fish infected ith the disease. When outbreaks of kidney disease occur during periods of oderate or warm water temperatures, the mortality rates may reach explo-ve proportions. Earp, Ellis and Ordal (1953) have presented epidemiologi-l observations on outbreaks of kidney disease occurring in chinook, sock-ye and coho salmon. In one outbreak of kidney disease in fall chinook sal-ion occurring at relatively high water temperatures, the weekly mortality ite rose from less than 1 percent to 26.6 percent in a period of eight weeks eginning in early July. The mean weekly water temperatures during this eriod ranged between 55° and 65° F. In an outbreak of kidney disease in pring chinook salmon the weekly mortality rose from just over 1 percent o 35 percent in a period of 11 weeks. During this period mean weekly vater temperatures varied from 47° to 54° F. In an outbreak of kidney isease in a stock of sockeye salmon the mortality rose from around 1½ ercent to over 24 percent in a period of four weeks, even though water emperatures were moderate, ranging from 47° to 51° F.

In our experience, the disease is more widespread in stocks of chinook nd sockeye salmon, but recently instances of serious losses in coho salmon ave occurred. Little opportunity is offered for the study of the possible ccurrence of the disease in chum and pink salmon since these species remain in fresh water for only a short period before migration to the sea. It is known that the disease remains in infected stocks of chinook and coho salmon moved to artificial salt-water rearing ponds (Earp, Ellis and Ordal, 1953). Although most studies on kidney disease have been carried out in hatcheries, the disease has also been found in wild fingerling salmon. The disease is also known to affect species of trout as shown by Belding and Merrill (1935), Wales,[5] and S. F. Snieszko.[6]

The etiological agent of kidney disease is fastidious in its growth requirements. It has been found to grow relatively rapidly on minced chick embryo tissues but slowly and with a prolonged lag phase on artificial culture media. In experimental infections introduced by injection and feeding of the agent, a long incubation period, usually from 15 days to in excess of 40 days is characteristic of the disease. Kidney disease has been produced in healthy stocks of young salmon both by feeding and by injection of pure cultures grown on minced chick embryo tissues and on artificial culture media, and the etiological agent has been reisolated from experimentally infected fish. Koch's postulates have therefore been fulfilled.

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[5] Wales, J. H. Unpublished manuscript.

[6] Personal communication.

The results of experiments on therapy have not been consistent. In field experiments on therapy, using sulfadiazine and aureomycin, mortality rates have been reduced but the disease has not been eliminated. In one laboratory experiment 40 sockeye salmon yearlings about 5 inches in length were injected with a pure culture of the etiological agent of kidney disease grown on chick embryo tissues. The fish were divided into two equal groups: one group was fed sulfadiazine at the rate of 12 grams per 100 pounds of fish for 10 days followed by 6 grams per 100 pounds of fish for an additional 10 days. The results of this experiment are presented graphically in Figure 1.

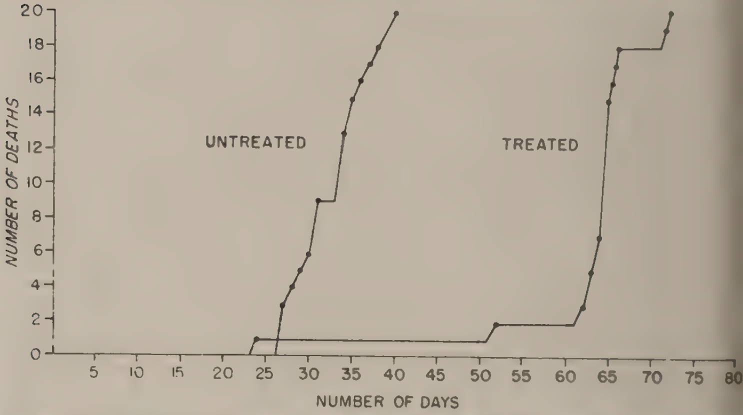

FIGURE 1.—Cumulative mortality curves of two groups of sockeye salmon inoculated with the etiological agent of kidney disease. The treated group received sulfadiazine in the food for the first 20 days. From Earp, Ellis and Ordal (1953).

The untreated fish died about 25 to 40 days after inoculation. The group fed sulfadiazine for 20 days had a delayed mortality period, and the majority of the fish died about 40 to 50 days after the sulfonamide was removed from the food. The most logical explanation is that some of the diplobacilli of kidney disease were still present and capable of developing after therapy was discontinued.

Some of the most important agents of disease in salmon are found among the myxobacteria. Many of the myobacteria possess life cycles including a communal fructification stage closely analogous to that which occurs among the myxamoebae. Although most of the myxobacteria which have been described come from soil (Breed, Murray and Hitchens, 1948), we have found that they are commonly present in the aqueous habitats. The problem of studying the pathogenic species is therefore complicated by the presence in water of large numbers of saprophytic and parasitic forms which have not been adequately described. Taxonomic studies on the myxobacteria oc-ring in fresh water are being carried out by E. J. Ordal. Myxobacteria m the marine environment are being studied at the University of Wash-ton by T. J. Starr.

The first myxobacterium found to be pathogenic to fish was *Chondro-cus columnaris*. This organism was originally isolated in pure culture in summer of 1942 by Ordal and Rucker (1944) during the course of an izootic in sockeye salmon fingerlings at the U. S. Fish and Wildlife Service tchery at Leavenworth, Washington. Experiments on transmission were rried out, and the disease, commonly referred to as "columnaris disease," s reproduced in salmonid fishes. Pure cultures of the etiological agent re reisolated from the experimentally infected fish, thus fulfilling Koch's stulates. A search for the primary source of the bacteria responsible for e epizootic in sockeye salmon led to the isolation of myxobacteria, identi-ble as *Chondrococcus columnaris,* from the surface lesions and from the ternal organs of adult chinook and sockeye salmon, steelhead trout *almo gairdneri*), *whitefish* (*Prosopium* sp.), squawfish (*Ptychocheilus egonensis*), chub (*Mylocheilus caurinus*), and suckers (*Catostomus* sp.) ken from the Columbia river. *C. columnaris* was also found in the organs moribund adult sockeye and chinook salmon held in large outdoor ponds the Leavenworth Hatchery. These fish had been trapped at Rock Island am on the Columbia River, and heavy mortalities had occurred during e period of holding. Once isolated the organisms were easily recognized as yxobacteria because of the shape and flexibility of the vegetative cells, e absence of a rigid cell wall and the characteristic myxobacterial motility young cultures. The occurrence of spherical and oval microcysts, and of olumnar or branching fruiting bodies which were not deliquescent, led to he assignment of the organism to the genus *Chondrococcus* following the ey to the family Myxococcaceae of the order Myxobacteriales proposed by tanier (1942).

The disease of the sockeye salmon fingerlings at the Leavenworth Hatchery was considered similar, if not identical, to a bacterial disease mong warm-water fishes which had been described by Davis (1923). Fish nd Rucker (1945) reported on the occurrence of this disease in cold-water fishes. Davis (1923) gave a comprehensive description of a new disease which he had observed in a variety of warm-water fishes, and noted hat it was of consequence only during periods of high-water temperatures. Although he was unsuccessful in his attempts at cultivation of the bacterium observed in the lesions, he provided strong presumptive evidence of the causal relationship of these bacteria to the disease. An excellent description was given of the bacteria present in large numbers in the lesions. In particular Davis noted that when material from a lesion was placed on a slide in a drop of water, characteristic movements of the bacteria occurred, leading to the formation of short column-like masses. This column formation was considered characteristic of the species for which Davis proposed the name *Bacillus columnaris*. Apparently the organism was not considered to be a myxobacterium, since Davis (1923) in describing *B. columnaris* stated as follows: "The bacteria are motile and probably possess flagella, although owing to the lack of facilities this has not been determined with certainty." However, to a bacteriologist, the myxobacterial nature of *B. columnaris* is suggested by the description of the vegetative cells occurring in lesions of infected fish.

The myxobacterium studied by Ordal and Rucker (1944) in its vegetative phase corresponded closely to *B. columnaris* in size, in shape, in flexibility and particularly in the characteristic movements, including the formation of column-like masses of cells. Studies with pure culture showed that the process of column formation represented an early phase in the production of aquatic fruiting bodies, in which microcysts were found after a period of maturation. Ordal and Rucker (1944) accepted the description of *B. columnaris* by Davis (1923) as a prior observation and in considering the taxonomy of the organism under study, retained the specific epithet "columnaris," but assigned the organism to the genus *Chondrococcus* as a result of the demonstration of its myxobacterial nature, and because of the production of oval or spherical microcysts in non-deliquescent fruiting bodies. It should be noted that the production of fruiting bodies in aqueous media, though a striking property, is not considered in determining the systematic position of a myxobacterial genus or species (see Breed, Murray and Hitchens, 1948).

The identity of *Chondrococcus columnaris* (Davis) Ordal and Rucker (1944) with *B. columnaris* (Davis 1923) has not been accepted by all investigators. Garnjobst (1945) isolated a myxobacterium from infected brown bullheads (*Ameiurus nebulosus*) at the U. S. Fish and Wildlife Service laboratory at Leetown, West Virginia, which she considered identical with *B. columnaris* (Davis 1923). This organism resembled *Chondrococcus columnaris* in its morphology and in its characteristic movements, but failed to produce microcysts and fruiting bodies and was designated as *Cytophaga columnaris*. No reference was made to the description of *Chondrococcus columnaris* by Ordal and Rucker (1944) and by Fish and Rucker (1945). Davis (1945) reported that *Cytophaga columnaris* was responsible for infections in brook trout (*Salvelinus fontinalis*) in the hatchery at Leetown, West Virginia, and that infections with this organism also resulted in serious mortalities among fingerlings and adult salmon at the U. S. Fish and Wildlife Service hatcheries at Leavenworth, Washington and Coleman, California. Davis (1947) reported that *Cytophaga columnaris* was responsible for outbreaks of disease in bullheads, salmon, and white crappies, and later Davis (1949), reported that *Cytophaga columnaris* was responsible for an epizootic resulting in the death of a large number of white crappies (*Pomoxis annularis*) in a reservoir near Pendleton, Oregon. In these reports no mention was made by Davis of the question of fruiting body production. On the other hand, Nigrelli (1943) reported that outbreaks of disease due to *Bacillus columnaris* occurred in several species of catfish at the New York aquarium. Subsequently, Nigrelli and Hutner (1945) reported on an epizootic in killifish (*Fundulus heteroclitus*) due to a similar organism. The myxobacteria present in the lesions were isolated in pure culture and

teriological studies carried out. Typical swarming and fruiting body
duction were observed in both fresh and cultured material, and the or-
ism was diagnosed as *Chrondrococcus columnaris*. Nigrelli and Hutner
45) reported further that the organism isolated from killifish was
rphologically and physiologically similar to a strain of *Chondrococcus*
umnaris provided by Ordal and Rucker.

n view of the confusion in the nomenclature and taxonomic position of
etiological agent or agents of "columnaris disease," a few additional
servations are presented. Ordal (1945) carried out further studies on the
duction of fruiting bodies by *Chondrococcus columnaris* using a variety
strains isolated from both rough and salmonid fishes. It was found that
iting body production could be readily demonstrated by placing auto-
ved fingerling salmonid fish in large flasks containing sterile tap water,
d inoculating with the culture under study. Fruiting bodies, usually
lumnar, sometimes highly branched structures, appeared after a few days.
e fruiting bodies extended a distance of 0.5 to 3 millimeters above the
rface of the fish, and in some instances were packed closely together,
vering almost the entire surface of the fish. It was concluded that the
iting bodies occurring in dilute aqueous solutions could be considered as
rmal types. Sometimes atypical fruiting body production was observed,
rticularly with old laboratory cultures of *Chondrococcus columnaris*.

Borg[7] carried out further studies on the production of fruiting bodies
Chondrococcus columnaris and found that freshly isolated strains
aracteristically produced fruiting bodies in which microcysts appeared
ter a period of maturation. The provision of a suitable dilute aqueous
edium and the maintenance of aerobic conditions were found to be neces-
ry conditions for the production and maturation of fruiting bodies. A
ries of strains of *Chondrococcus columnaris* carried in the laboratory for
eriods of up to three years were also examined. It was found that some of
ese strains produced colony types on solid media widely different from
e original isolates. Some of these cultures failed to produce fruiting bodies,
rming instead an envelope of slime in which bacterial cells were imbedded.
Vith other strains definite fruiting bodies were observed, but maturation
id not necessarily occur, and in these cases the microcysts were relatively
ew in number. Apparently the production of fruiting bodies is a complex
rocess, and degenerative changes may occur in cultures of *Chondrococcus*
olumnaris when carried on artificial culture media leading to selection of
trains which are incapable of production or maturation of fruiting bodies.
This situation is not unique with *Chondrococcus columnaris*, since a num-
er of investigators (Snieszko, McAllister and Hitchner, 1943; Woods[8])
ave shown that a similar situation exists with species of fruiting myxo-
acteria isolated from soil. These findings indicate the desirability of test-
ng for production of fruiting bodies in freshly isolated strains of aquatic
myxobacteria.

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[7] Borg, Alfred Francis 1948. Studies on myxobacteria associated with diseases in salmonid fishes. 162 pp. Ph.D. thesis, University of Washington.

[8] Woods, Nellie Angelina 1948. Studies on the Myxobacteria. 75 pp. M.S. thesis, University of Washington.

Borg[7] considered the question of the taxonomy of the myxobacteria isolated from outbreaks of columnaris disease and agreed with Ordal and Rucker (1944) that the organism was properly named *Chondrococcus columnaris*. With respect to the organism isolated by Garnjobst (1945) it was suggested that non-fruiting strains of *Chondrococcus columnaris* might exist in nature and that *Cytophaga columnaris* might be an example of such a strain. Another possibility is that Garnjobst was dealing with a strain of *Chondrococcus columnaris* which had lost its capacity to produce fruiting bodies as a result of cultivation on laboratory media.

Davis (1946) as noted above, reported that infections with *Cytophaga columnaris* resulted in serious mortalities in fingerling and adult salmon at the U. S. Fish and Wildlife Service hatcheries at Leavenworth, Washington and Coleman, California. The outbreaks at Leavenworth, Washington were investigated by Ordal and Rucker (1944) and the etiological agent diagnosed as *Chondrococcus columnaris*. Cultures isolated at Leavenworth from sockeye salmon fingerlings in 1942 by Rucker[9] were sent to Dr. H. S. Davis in 1942. Through the courtesy of D. W. Slater, cultures of myxobacteria isolated from outbreaks of columnaris disease at the Coleman Hatchery and elsewhere were made available. These cultures were studied by Ordal[10] who found that some cultures produced typical fruiting bodies and were readily recognizable as *Chondrococcus columnaris*. Other cultures produced abortive fruiting bodies, such as often occur in old laboratory cultures of *Chondrococcus columnaris*. Unfortunately the culture of *Cytophaga columnaris* isolated by Garnjobst from bullheads at the Leetown Hatchery was not available to us for comparative study. However, Davis (1947) reported that additional outbreaks due to *Cytophaga columnaris* occurred at the Leetown Hatchery. Hence, should further outbreaks of columnaris disease occur at this station, it might be possible to resolve the discrepancy in nomenclature by studying freshly isolated strains of the etiological agent.

Chondrococcus columnaris is an important agent of disease, both in the hatchery and the natural habitat. In the summer, *Chondrococcus columnaris* can be found in impoundments behind dams, in lakes, streams and rivers. It is difficult if not impossible to determine the numbers of fish killed in naturally occurring epizootics because of predation, sedimentation and decomposition but evidence has accumulated that heavy mortalities can occur. For example, each summer for a number of years large numbers of dead and moribund rough and salmonid fishes have been found in shallow waters along the shores of Lake Washington. These fish show the presence of columnaris disease and *Chondrococcus columnaris* can be isolated from the majority of the specimens taken.[11]

In our experience, the strains of *Chondrococcus columnaris* which have been isolated and tested at comparable water temperatures, fall into two categories with respect to virulence. The cultures isolated and tested for

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[9] **Rucker, Robert Raymond 1944. A study of saprolegnia infections among fish. 92 pp. Ph.D. thesis, University of Washington.**

[10] **Ordal, E. J. Unpublished data.**

[11] **Ordal, E. J. Unpublished data.**

lence, including strains obtained from rough fish and salmonids in West-
Washington and from rough fish in the Columbia River, are character-
d as low virulence strains. It is true that they can cause mass mortalities
atcheries and in natural bodies of water when water temperatures reach
her high values. However, the infection is slow and insidious and tre-
ndous tissue damage normally occurs before death ensues. The disease
sed by these strains in hatcheries can be controlled to a degree by ap-
priate therapy with sulfonamides and pyridylmercuric acetate. Studies
therapy in fingerling salmon have been carried out by Slater (1948),
hnson and Brice (1953), R. F. Foster,[12] and Rucker.[13]

A number of strains of *Chondrococcus columnaris* which possess ex-
mely high virulence have been isolated from both adult and young sal-
n in the Columbia River.[14] When tested in the experimental hatchery,
ains of this type cause fulminating infections in young salmon merely by
ntact or ingestion, with mortalities often reaching 100 percent in periods
12 to 24 hours. The etiological agent can be recovered in almost every
stance from the organs of the infected fish. Young salmonid fish infected
ith strains of *Chondrococcus columnaris* of high virulence seldom show
rge external lesions. Apparently death occurs before gross, external mani-
stations of the disease appear. It was found by Dyar and Ordal (1946)
at a strain of *Chondrococcus columnaris* of high virulence for salmon
ssessed a lipoid component in the cell membrane. This component was
ther absent or quantitatively less abundant in freshly isolated strains of
w virulence. After cultivation on laboratory media for a period of 18
onths, the culture was again tested. It was found that pathogenicity for
lmon was lost, and the lipoid component was no longer present. Although
e property of high virulence is readily lost on subculture on laboratory
edia, it has not yet been possible to develop strains of high virulence from
trains of low virulence by serial passage through salmonid fishes. Hence the
atural source of these strains is still a mystery. There is a possibility that
he strains of high virulence arise as a result of sexual recombinations in
he complex life cycle of the organism. This question is under investigation.

Another well defined myxobacterium which is of considerable importance
s an agent of disease in young salmon is *Cytophaga psychrophila*. This
rganism was isolated by Borg[7] and found to be the etiological agent in
pizootics in coho salmon occurring at relatively low mean water tempera-
ures, *i.e.* 40° to 50° F. The disease was found present in six different
atcheries, and one group of approximately one million coho salmon finger-
ings suffered a 31 percent loss. Borg noted that during the course of an
pizootic some fish develop lesions just anterior to the tail, some fish show-
d lesions on the isthmus or over the back just anterior to the dorsal fin,
while others become abnormally dark in color with no apparent surface
lesions. *Cytophaga psychrophila* was isolated from the organs and lesions of
the diseased fish. Three additional types of myxobacteria were isolated from

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[12] Personal communication.

[13] Rucker, R. R. Unpublished data.

[14] Rucker, R. R. and E. J. Ordal. Unpublished data.

the lesions. These myxobacteria could be distinguished from each other and from *Cytophaga psychrophila* by morphology, biochemical reactions and by their ability to grow at temperatures of 75° F. or higher. *Cytophaga psychrophila* grew over the range 37° to 68° F. but failed to grow at 75° F on the medium employed. The organism was diagnosed as a species of *Cytophaga* since neither fruiting bodies nor microcysts were formed by freshly isolated strains. The specific epithet "*psychrophila*" was applied to the organism because of the low maximum temperature of growth, and because of its role as an agent of disease at low water temperatures.

Further studies have been carried out by Earp and Ordal.[15] It has been found that epizootics due to *Cytophaga psychrophila* occur every year in coho salmon in some hatcheries. In some outbreaks the fry are affected, in others the disease begins in the fingerling stage. The manifestations of the disease, as well as the course of a given epizootic, are profoundly influenced by prevailing water temperatures. The disease usually occurs in the spring when mean water temperatures are in the range of 40° to 50° F., and mortalities diminish with a rise in water temperatures. As a rule, the disease has run its course before the mean water temperatures reach 55° F. In a few outbreaks, mortalities have persisted to higher temperatures, *i.e.* around 60° F. The effect of temperature on the course of the disease has been investigated in the experimental hatchery. In one experiment a lot of approximately 2,000 fingerling coho salmon from a stock infected with *Cytophaga psychrophila* was brought to the experimental hatchery. These fish were held at a temperature ranging from 41° to 44° F. A heavy and persistent mortality occurred in these fish. Cultures were made at intervals and *Cytophaga psychrophila* was isolated from the majority of the dead or moribund fish sampled. A lot of approximately 180 fish was transferred to a separate trough and the water temperature raised to 55° F. The mortalities declined sharply after the first few days and after a week *Cytophaga psychrophila* could no longer be isolated. The disease persisted in the fish held at 41° to 44° F. and eventually all perished. The manifestations of the disease are also dependent upon water temperatures, and definite variation in virulence has been noted in strains of *Cytophaga psychrophila*. In one outbreak the daily mortality rate reached a level of 10 percent. At low mean water temperatures, *i.e.* in the range 40° to 45° F., relatively few gross external lesions are noted; however there is often a mantle anterior to the dorsal fin or near the peduncle. The fish characteristically darken in color before death. *Cytophaga psychrophila* can almost invariably be isolated in pure culture from the blood or organs of moribund fish, and usually from the mantle if it is present. At higher water temperatures ulcers or eroded areas are frequently found. Under these conditions cultures made from the blood or organs usually yield *Cytophaga psychrophila*, though occasionally other myxobacteria are also present. Cultures made from the eroded areas usually yield *Cytophaga psychrophila* and in addition several characteristically different types of myxobacteria. The latter are apparently secondary invaders.

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[15] Earp, B. J. and E. J. Ordal. Unpublished data.

The disease occurs mainly in coho salmon, though *Cytophaga psychro-* *ila* has been isolated from organs and lesions during the course of an tbreak of disease in sockeye salmon. Chinook salmon appear to be rela- ely resistant. It has, however been noted that during the course of an izootic in coho salmon, moderate rises in mortality rates may occur in rallel ponds of chinook salmon. In these instances *Cytophaga psychro-* *ila* can often be isolated from the gills but not from the organs of the inook salmon.

A number of other aquatic myxobacteria have been found to be patho- nic to salmon. In ordinary gill disease, myxobacteria are regularly iso- ted from the gills of affected fish. This type of gill disease is readily con- olled with pyridylmercuric acetate or roccal and the myxobacteria are not coverable from the organs of the fish. The specific characteristics of the yxobacteria isolated vary in different outbreaks. Apparently these myxo- acteria are of limited pathogenicity.

Gill disease can take a more severe form, particularly in young chinook lmon. Here specific myxobacteria, as yet unnamed, can cause a generalized fection in addition to development on the gills. The etiological agent can e recovered from both the gills and organs of the fish and the disease does ot respond readily to treatment with pyridylmercuric acetate or roccal.

A number of myxobacteria with definite invasive powers have been found n young salmon in conjunction with outbreaks of other types of disease. ne interesting type produces ulcers in sockeye salmon at moderate tem- eratures when *Chondrococcus columnaris* is inactive.

DISEASES IN SEA WATER

A series of investigations, largely exploratory in character, have been carried out on the occurrence of disease in salmon in sea water (Earp and Ordal).[16] Selected findings are presented in brief. The investigations on young salmon have been largely confined to fish reared in ponds supplied with pumped sea water. A number of diseases due to bacteria and other organisms have been found. One disease in young chinook salmon resembled columnaris disease but was due to a highly fastidious, halophilic myxobacterium. A disease in coho salmon, characterized by large muscular absceses, was found to be due to a species of *Lactobacillus*. The disease was slow and chronic but eventually the entire population was lost. Another disease is due to a marine species of *Vibrio*. The disease is characterized by extensive hemorrhages throughout the musculature and the internal organs in which the vibrio is found in very large numbers. The disease first appears in the ponds in late April or May and continues through the summer during the period when the water temperatures approach 50° F. Bloody areas appear on the exterior surfaces of the fish and mortalities climb rapidly to high levels. All species of salmon are affected with catastrophic mortalities occurring in pink and chum salmon and lesser mortalities in chinook and coho salmon. Similar pathology has been found in Pacific herring (*Clupea*

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[16] Earp, B. J. and E. J. Ordal. Unpublished data.

pallasi) seined in Puget Sound. Various lots of these herring placed in live boxes died within 48 hours with hemorrhages in musculature and internal organs. The vibrio can be isolated from the lesions and blood of affected fish on simple peptone media provided sodium chloride is added in at least physiological concentrations. No growth is obtained on media without the addition of sodium chloride. Healthy fish injected with pure cultures of the vibrio usually die within 24 hours and exhibit the characteristic lesions. Therapy with sulfonamides, as employed for outbreaks of furunculosis, has been of value in controlling this disease.

Recently, an outbreak of disease with similar pathology occurred in rainbow and steelhead trout in fresh water at the Vancouver Hatchery of the Washington State Department of Game. This outbreak was investigated by Rucker and Ordal[17] and the etiological agent was a halophilic vibrio resembling closely the organism responsible for the outbreak in salmon in sea water. The disease was noted following the feeding of salmon viscera and marine scrapfish. Heavy mortalities continued in legal-sized rainbow trout until sulfonamide therapy was given.

Tuberculosis has been found in adult chinook salmon taken during migration up the Columbia River.[18] Since the disease was in an advanced stage of development it is likely that it was contracted at sea. Further evidence to this effect has come from the demonstration of tuberculosis in commercially caught chinook salmon taken near the mouth of the Columbia River.

It seems likely that disease due to micro-organisms may be of greater importance in the marine habitat than has hitherto been realized.

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[17] Rucker, R. R. and E. J. Ordal. Unpublished data.

[18] Earp, B. J., T. McKee, and E. J. Ordal. Unpublished data.

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THERAPY OF BACTERIAL FISH DISEASES

S. F. SNIESZKO

Microbiological Laboratory
U. S. Department of the Interior, Fish and Wildlife Service
Leetown, West Virginia [1]

ABSTRACT

During the past decade considerable progress has been made in the therapy of bacterial fish diseases. This progress was possible largely because of the introduction of powerful chemotherapeutic agents such as sulfonamides and antibiotics.

Fish furunculosis can be treated with very good results with sulfamerazine, sulfamethazine, and sulfaguanidine as well as by chloramphenicol and terramycin. Ulcer disease caused by *Hemophilus piscium* resists treatment with sulfonamides but responds well to the above mentioned antibiotics.

Chemotherapy of fish diseases caused by pseudomonads is possible with chloramphenicol, but sanitary measures are preferred. External disinfections with Roccal and pyridylmercuric acetate (PMA) are satisfactory in treatment and prophylaxis of gill diseases which are probably caused by superficial infections with myxobacteria. Sulfonamides are helpful in systemic infections with myxobacteria and are also being used with some success for the control of a recently described kidney disease of salmonoid fishes.

Also described are methods of control of other fish diseases and of immunity in cold-blooded animals and fishes. Most of the drugs in the described treatments may be toxic to fishes, and therefore should be used with caution.

INTRODUCTION

The therapy of bacterial diseases of fishes is essentially the same as that or higher vertebrates. However, in man and larger mammals, chemotherapeutic treatments are usually given to individuals and not to whole popuations. Group treatment is applied normally to poultry because individual care, except especially valuable birds, would not be economical. The same s true with fishes. In the therapy of fish diseases, external disinfectants are used when the pathogenic bacteria produce superficial infections as in some forms of gill disease. Internal treatments with chemotherapeutic drugs, including antibiotics, are given for infections of the intestinal tract, internal organs, tissues, or in cases of septicaemias, such as in ulcer disease, furunculosis, myxobacterioses, and kidney disease.

Sulfonamides and antibiotics are the best known and most effective of the true chemotherapeutic drugs. Certain general principles should be observed in chemotherapy with sulfonamides (Northey, 1948) and antibiotics (Baron, 1950; Chandler, 1953). The experimental studies carried out in the laboratories provide information on which the final evaluation must be made through extensive and well controlled field trials. Most of the chemotherapeutic drugs should be given in sufficiently large doses and fo long enough time to control the infection. On the other hand, a too pro longed treatment may be dangerous because of the possible toxic effect o the drug and the development of drug-resistant strains of pathogens. Th author has been advised that in some cases of furunculosis, treatment wit increased dosage of sulfonamides was not effective, and antibiotics have ha to be used. Cultures of *Aeromonas salmonicida* isolated from such infecte fish were highly resistant to sodium sulfamerazine *in vitro*. The indiscrim inate use of drugs is very dangerous. Wholesale treatment of all disease with a single drug is just as undesirable as "shot gun" therapy. Good san tation should be stressed and given preference over therapy. Drugs shoul be used only when infectious agents penetrate the barricade of sanitation In this review some well known fish diseases are discussed in relation t treatments of proven value introduced in recent years.

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[1] P. O. Kearneysville, West Virginia.

DISEASES CAUSED BY PSEUDOMONADS

Pseudomonads are common water bacteria. Some of them have bee described as pathogens of cold-blooded vertebrates. Recently some specie of these bacteria, which are active fermenters of various organic source of carbon, were placed in the new genus *Aeromonas*. To this genus [2] belon two important fish pathogens: *Aeromonas liquefaciens* (formerly *Pseudo monas punctata*) which is the agent, or co-agent of infectious dropsy o carp and other fishes, and *Aeromonas* (formerly *Bacterium*) *salmonicid* the etiological agent of fish furunculosis (Griffin, this symposium). Sinc both bacteria cause septicemia, the therapeutic and preventive measure that may be applied are chemotherapy, increase of immunity or resistance and sanitary measures.

Fish furunculosis.—"No fish disease is to be feared more by the hatcher man than furunculosis, or the 'great red plague' of salmon and trout (McCraw, 1952). Whenever outbreaks of this disease occur in trout hatch eries, most of the brook trout (*Salvelinus fontinalis*) are lost and mortali ties among salmon, brown trout (*Salmo trutta*), and even some non-sal monoid fishes are heavy. Of the salmonoid fishes, rainbow trout (*Salm gairdneri*) appear to be most resistant to this disease, but occasional epi zootics with heavy losses have been reported. Since furunculosis was de scribed 60 years ago, concerted efforts have been made to understand it nature and to develop methods of control (McCraw, 1952). Sanitary meas ures provided the only effective control of furunculosis prior to the intro duction of sulfonamides and antibiotics. Infected fish were destroyed, th hatchery was disinfected, and trout cultures were started anew from un infected or disinfected eggs (O'Donnell, 1947). Acriflavine (Smith, W. W. 1942, 1944) and sulfo-merthiolate (Gee and Sarles, 1942; Snieszko an Friddle, 1948) were found to be the best among the chemicals tested fo disinfection of fish eggs.

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[2] As recommended for the 7th edition of Bergey's Manual of Determinative Bacteriology Williams and Wilkins, Baltimore, Md.

The treatment of fish populations infected with furunculosis became ssible with the introduction of those sulfonamides which are also effec- e in the control of infections caused by gram-negative bacteria (Northey, 48). Sulfonamides and other drugs were tried in the treatment of furun- losis by Gutsell (1946, 1948) who found that sulfamerazine was most ective; sulfathiazole and furacin also reduced mortalities considerably. olf (1947) confirmed Gutsell's results. Further studies (Snieszko, Gut- ll, and Friddle, 1950) have shown that sulfamethazine, a drug closely lated to sulfamerazine, although slower acting, is apparently equally ef- ctive in the treatment of brook trout populations infected with *A. sal- onicida*. Treatment of furunculosis among brown trout with a mixture sulfamerazine and sulfaguanidine gave satisfactory results (Flakas, 950) and should be further investigated.

Experiments on dosage were carried out with infected fingerling and earling brook trout (Gutsell and Snieszko, 1949a) who tested dosages of 4 to 260 milligrams of sulfamerazine per kilogram of fish per day (2 to 2 grams per 100 pounds). The optimum dosage was found to be 176 milli- ams per kilogram of trout per day (8 grams per 100 pounds). With in- eased dosage (12 grams) the losses were slightly larger than at the 8- am level, probably due to toxicity of the drug. The 4-gram rate though ss effective than 12 grams reduced mortalities drastically. The 6-gram osage gave nearly as good results as the 8-gram. However, the 8-gram osage rate is recommended since it furnishes a margin of safety without sses attributable to the toxicity of the drug. The dosage of 8 grams per 00 pounds resulted in apparently complete cure of all the surviving earling brook trout. *A salmonicida* was recovered from the undersized shes (runts) among fingerling brook trout which had been treated at the -gram daily rate. No undersized fishes and no carriers were found among he trout which survived in the controls. Since all small trout died in the ontrols, it seems possible that the runts in the treated lots received enough nedicated food to arrest the disease but not enough to eliminate the patho- enic bacteria. Treatment of ungraded trout with sulfamerazine can be ex- ected to suppress furunculosis, but not to eliminate it from the infected opulation. Therefore grading is necessary for effective chemotherapy of rout when the drugs are given with food.

In artificially infected 2-year-old brown trout, complete elimination of *A. salmonicida* was accomplished by a sulfamerazine-sulfaguanidine mix- ure, while sulfamerazine alone suppressed the symptoms of the disease without eliminating *A. salmonicida* from all fishes in a treated population (Flakas, 1950). On the basis of this observation and routine treatment of brown trout at one of the Wisconsin hatcheries, Flakas recommended a "multiple-sulfonamide" therapy. During the first 3 days, the trout should receive a mixture of 12 grams of sulfamerazine with 6 grams of sulfaguanidine for 100 pounds of fish per day. This treatment should be followed by a 7-day regimen of 6 grams of sulfamerazine and 4 grams of sulfaguanidine daily. It would be most interesting to repeat these experiments with brown trout and brook trout of various age groups since it is

known that tissue levels of sulfonamides vary in trout of different siz
(Snieszko and Friddle, 1951, 1952) and that the brown trout and bro
trout react differently to sulfamerazine (Gutsell and Snieszko, 1949b

In the evaluation of any new therapeutic agent, it is essential to dete
mine: its effectiveness *in vitro* and *in vivo* against various microorganism
the optimum therapeutic dosage; the toxicity to animals (or humans
and the effective concentrations of the drug in the blood, urine, or inte
tinal tract. When this information is available, the drug can be used i
telligently and with a considerable degree of safety. The efficacy of su
famerazine therapy of fish furunculosis was established before most of t
properties of this drug towards the pathogen or the host were know
Treatments were undertaken in advance of careful study because any kin
of promising therapy was urgently needed. However, to put sulfonami
therapy on a rational basis, it was necessary at least to determine t
response of fishes to sulfonamides, the rate of absorption from the i
testinal tract, retention in active form in the tissues, and elimination fro
the body.

A number of sulfonamides have been tested *in vitro,* for their bacteri
static action against *A. salmonicida.* Sulfathiazole and sulfadiazine showe
strong bacteriostasis; sulfamerazine was half as effective and sulfametha
zine proved to be only weakly bacteriostatic (Smith and Nigrelli, 1947
In the trouts however, sulamerazine and sulfamethazine produce highe
tissue concentrations than do other sulfonamides (Snieszko and Friddle
1951); this fact may explain their greater effectiveness in the therapy o
furunculosis. In the testing of the effect of sulfamerazine on trout, Gutsel
and Snieszko (1949b) found that the growth rate of fingerling rainbo
trout was not affected by prolonged treatment at rates of 5, 10, and 1
grams of the drug per 100 pounds of fish per day. The growth rate o
fingerling brook trout was reduced by higher dosages. The response o
brown trout was most striking since all three dosage rates arrested th
growth completely during the treatment (see also under "Toxicity")
Furunculosis appeared in the treated and control lots of brown trout
Apparently the good absorption of sulfamerazine by brown trou
(Snieszko and Friddle, 1951, 1952) did not compensate for the reduce
amount of the medicated food which the experimental brown trout took
The tissue concentration of the drug varies considerably among individual fishes even in a well graded trout population which has been treate
for a number of days with food containing sulfamerazine. The tissu
concentration also varies somewhat among fishes of uniform siz
given uniform doses of the drug in gelatin capsules. The relationshi
between the rate of feeding of the medicated food and the tissue concentration of sulfamerazine is very important. When the same amount o
drug was mixed with variable quantities of food, the tissue levels o
sulfamerazine were highest in those fish receiving the least food. This fact
does not justify grossly underfeeding the treated fish, since that procedure
would deprive of medication the weaker or smaller fish which are most
difficult to treat (Gutsell and Snieszko, 1949a). In higher vertebrates and

nans, therapy is usually started with a high initial dose and then owed by lower maintenance doses. The experimental evidence seems to icate however, that, in fish, a high initial dose has little effect on the ue level of sulfamerazine during the subsequent period of maintenance age (Snieszko and Friddle, 1952). Flakas (1950) recommended a high tial dosage. Additional and very precise tests are required to determine value of high initial dosages in the treatment of fish diseases with fonamides. Further experiments on the treatment of furunculosis and er fish diseases with combinations of sulfonamides or with sulfonamides d antibiotics also seem to be much needed.

The data on the tissue levels of sulfonamides in trout also explain the wer action of sulfamethazine in comparison with sulfamerazine. The o are equally effective in the treatment of fish furunculosis. Sulfamethae however, is less bacteriostatic (Smith and Nigrelli, 1947) and is sorbed at a slower rate than sulfamerazine. The final tissue levels of e two drugs are equal (Snieszko and Friddle, 1951).

In addition to sulfonamides, terramycin and chloramphenicol are effece in the treatment of furunculosis (Snieszko, Griffin, and Friddle, 52). At present sulfonamides are recommended for economic reason. ntibiotics are recommended for the treatment of furunculosis if ulcer sease also is present, or if the fish do not respond well (drug-resistant rain of *A. salmonicida*) to sulfonamide treatment (Anonymous, 1953).

Fish dropsy and other diseases.—The infectious fish dropsy seems be important in warm-water fishes as is furunculosis in trout and lmon. Schäperclaus (1930) was the first to suggest that the most likely iological agent of this disease is a common water bacterium, *Aeromonas quefaciens* formerly *Pseudomonas punctata* (for synonyms see Griffin, is symposium).

Recently some German and Russian authors reported that in some ases, the primary cause of infectious fish dropsy is a virus. Nevertheless, *eromonas liquefaciens* and possibly other pseudomonads play a primary r at least important secondary role in a number of fish diseases (Griffin, is symposium). Recently, reports have been published in Canada (Reed nd Toner, 1942), in this country (Seaman, 1951; Wagner and Perkins, 952) and in Germany (Heuschmann, 1952) on diseases of trout caused y this pathogen. Obviously, the control of such diseases is important in ractical fish culture.

Numerous German papers deal with the control of infectious dropsy y pond sanitation, quarantine, fish-management techniques, immunizaion, or even deliberate exposure to infection in order to eliminate the usceptible individuals from the population. Since the literature on this ubject is voluminous, only certain of the more significant references will e given: Heuschmann, 1953; Schäperclaus and Mann, 1939; Schäperlaus, 1941; and Wunder, 1949.

The author knows of only four reports of successful chemotherapy of iseases attributed to *Aeromonas liquefaciens* (formerly *Pseudomonas hydrophila*). Most of the frogs which Smith (1950) treated for "red leg" with a solution of chloramphenicol given by gastric intubation recovered a remained healthy during the observation period of several months. Ambru Ambrus, and Harrison (1951) prevented "red leg" by keeping frogs water containing 50 milligrams of chloramphenicol per liter. Seama (1951) obtained good results with sulfamerazine in rainbow trout suffe ing from infections with pseudomonads, as did Wagner and Perki (1952), with a mixture of sulfathiazole and sulfamethazine and "som antibiotics (details not reported). Terramycin at a concentration of 0.0 microgram per milliliter was found to be bactericidal to this organis *in vitro*. The reports quoted above indicate that the chemotherapy of fi diseases caused by pseudomonads is possible. It will be interesting to s how effective such therapy may be, and whether it can be applied to t treatment of fish dropsy in warm-water ponds.

ULCER DISEASE

Unquestionably there is more than one "ulcer disease" of fishes (Griffi this symposium). Snieszko (1952) suggested that the term "ulcer diseas should be limited on the basis of priority and infection experiments to t disease of trout caused by *Hemophilus piscium*. The first but unsucessf attempt at therapy of this disease was reported by Fish (1934) wh recommended dips in copper sulfate in early stages of the infectio Tunison and McCay (1937) tried sulfanilamide and other chemical but without success. Wolf (1939) tested various disinfectants and diet but obtained some success only with sulfamerazine (1947). Experimen at Leetown indicated that sulfamerazine therapy was ineffectual. It possible that the outbreak which was controlled by sulfonamides (Wol 1947) was caused by a mixed infection of *A. salmonicida* and *H. pisciu* or that other undetermined factors were involved. At Leetown and othe hatcheries, several such mixed infections have occurred, the true etiolog of which could be disclosed only by bacteriological examination. Th test carried out *in vitro* with Difco "Sensitivity Discs" indicated that th zones of inhibition of growth were widest with chloramphenicol, somewh narrower with terramycin, and even smaller with aureomycin. In th *in vivo* experiments carried out with fingerling and adult brook trou chloraphenicol and terramycin administered orally at a rate of 50 milli grams per kilogram of fish per day were equally effective in the treatmen of the ulcer disease and furunculosis. Aureomycin had no effect. Treatmen with chloramphenicol gave fewer recurrences (Snieszko, Friddle, an Griffin 1951; Snieszko, Griffin, and Friddle 1952). It would be interestin to discover the reason for ineffectiveness of aureomycin *in vivo*.

INFECTIONS CAUSED BY MYXOBACTERIA

Myxobacterioses.—As far as we know now, fishes are the only animal which are subject to diseases caused by representatives of this group o bacteria which are common in soil and water. It is likely that more tha one species of myxobacteria is pathogenic to fishes (Griffin; Rucker *et al*

s symposium). Fish usually succumb to "columnaris disease" (Davis,
46), when the temperature of water rises to about 20° C. Psychrophilic
ms pathogenic at lower temperatures also have been reported. Davis
946) recommended treatment with 1:2000 copper sulfate; this solution
parently was satisfactory only in the early stages of the disease when
infection was still superficial. Fish and Rucker (1945) were not able
control myxobacterioses with any of the several surface disinfectants
ich they tested. The only surface disinfectant of promise is pyridyl-
rcuric acetate.[1] Slater (1948) was the first to investigate the chemo-
erapeutic effects of various sulfonamides for the control of this disease
fingerling chinook salmon (*Oncorhynchus tschawytscha*). The best
sults were obtained with sulfamerazine and sulfadiazine; sulfamethazine
as somewhat less efficacious. Sulfathiazole was without effect and food
ntaining sulfanilamide was rejected by the fishes after several days
treatment. All sulfonamides tested were administered orally at a rate
12 grams per 100 pounds of fish per day for a week, and the dosage
as reduced by half during the second week. Sulfonamide therapy had
ly a temporary effect and the losses due to myxobacterioses increased
ortly after treatment was discontinued. These results are in agreement
ith the observations of Snieszko and Friddle (1951) who reported that
lfamethazine was absorbed at a slower rate than sulfamerazine in
ngerling brook trout, kept at the temperature of 12°–13° C., and that
lfathiazole could hardly be detected in the trout tissues. Sulfanilamide
as toxic, probably because of its rapid absorption and the consequent
igh tissue levels. The action of sulfadiazine on myxobacterioses is most
markable since in brook trout, it produced a tissue concentration only
bout half that reached with sulfamerazine. Johnson (1951) confirmed
later's observations with rainbow trout treated with sulfamerazine. The
herapy recommended by Slater was again tried on a large scale by
ohnson and Brice (1952). Fingerling salmon of several species and trout
hich developed myxobacterioses at temperatures of 16° to 21° C.
60° to 70° F.) were treated with sulfamerazine and sulfadiazine as
ecommended by Slater. This therapy arrested mortalities among coho
almon (*Oncorhynchus kisutch*) and rainbow trout as long as it was con-
inued. It had no effect on chinook salmon and the results were dubious
ith cutthroat trout. It is possible that the species of fish that did not
espond to the treatment did not absorb enough sulfamerazine to develop
protective concentration in the tissues. Determination of the tissue levels
f sulfonamides would be particularly desirable in these two species since
t is difficult to believe that the drug resistance of the pathogen would
hange with the host. The results of Snieszko and Friddle (1952) have
hown that sulfamerazine is easily absorbed by rainbow trout. This species
lso responds well to the sulfonamide therapy of myxobacterioses. Since
one of the fish species studied by Johnson and Brice developed myxo-
acterioses at temperatures lower than 15° C. (60° F.), it seems logical

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[1] Bryant, Maurice, Jr. The use of PMA in treating columnaris. Mimeographed report. October 1950.

that the most practical method for prevention of these diseases would to rear fish at lower temperatures. When fish have to be reared in wa at higher temperatures, the source of the infection (possibly carrier should be eliminated from the water supply or the water should be fre from infectious agents. Perhaps automatic chlorination followed by chlorination of the water supply would be practical when water-borne fi diseases are causing heavy losses. It would be unreasonable to expect th even an effective treatment with sulfonamides should produce dural results while the high temperature of water and the presence of pathoge make continuous reinfection possible. It is of interest that the Feder trout hatchery at LaCrosse, Wisconsin, which receives chlorinated ci water which is dechlorinated before it reaches the fish (Sharp, 1951), practically free from communicable trout diseases.

Gill diseases.—Gill disease or diseases are some of the most comm maladies of young fishes. Due to the physiological role of gills in fishes, g diseases can be compared to pneumonia combined with kidney damage higher vertebrates. In warm-water fishes, gill infections of the hemo rhagic type are frequently caused by fungi belonging to the gene *Branchiomyces* (Schäperclaus, 1941). Other forms of gill diseases a caused by fungi belonging to the genus *Saprolegnia,* some by myxobacter (*Chondrococcus columnaris* and others), and some probably by und scribed bacteria (see also Rucker *et al.,* this symposium). Evidence is al available that malnutrition may be a primary cause of gill disease (W 1945, 1951a; Rucker, Johnson, and Kaydas, 1952). A hemorrhagic ty of gill disease (Wolf, 1937), apparently different from that caused by *Branchiomyces,* is frequent in the eastern United States. The above-me tioned diseases do not include infestations of the gills with various prot zoan and animal parasites. Griffin, and Rucker *et al.* (this symposium discussed the nature of gill diseases from a bacteriological point of view

The fact that gill diseases of trout and salmon frequently respond fave ably to treatments or prophylaxis with such disinfectants as roccal an pyridylmercuric acetate seems to support the theory that most of the either are caused by bacteria, or that in gill diseases of nutritional orig microorganisms may aggravate the symptoms greatly and play an ir portant role as etiological coagents.

The early methods of treatment of gill disease were adequately reviewe by Davis (1946). Considerable progress in the therapy has been mad during the past 10 years. One of the most important steps was replac ment of dips in copper sulfate by prolonged-treatment methods. Copp sulfate is apparently still useful in the control of some gill diseases amon farm-water pond fishes (Heuschman, 1953). Fish (1947) reported effecti control of gill disease by prolonged treatment with roccal (the trade nan for a 10-percent solution of high-molecular alkyl-dimethyl-benzyl-an monium-chlorides). He recommended that the roccal be evenly distribut in water at a concentration of 1:50,000 and the fish treated for 1 hou Since the composition of roccal is not constant the bactericidal and tox properties may vary in different batches (Rucker, 1948; Rucker, Johnso d Ordal, 1949). In hard water calcium and magnesium bicarbonates atly reduce the bactericidal efficiency of quarternary ammonium comunds (Chambers, Weber, and Bryant, 1953). The chelating agents unteract somewhat this effect of hard water (MacGregor and Elliker, 53).

Pyridylmercuric acetate (PMA) is another compound of value in the atment of gill diseases in salmon and trout, and of external protozoan estations in all fishes. It is used in its technical form (Van Horn and atz, 1946). Rucker (1948) found that a single 1-hour application of MA diluted to 2 p.p.m. will remove the bacteria from the surface of the ls and lead to a complete recovery of the infected salmon. Snieszko 949) confirmed Rucker's observations and Burrows and Palmer (1949) ported that PMA used at a rate of 2 p.p.m. not only gave excellent sults in treatment of gill diseases, but also of infestations with *Costia* d an unnamed stalked ciliate. PMA has a wide margin of safety; ngerling sockeye salmon (*Oncorhynchus nerka*) survived 90 minutes in ncentration of 1:45,000; the lethal concentration was 1:30,000. Burrows d Palmer did not give information on the sizes of the experimental fish, r the range of water temperature. They determined also that PMA was ot toxic to salmon fingerlings of two other species or to fingerling brook out and rainbow trout.

Wide-scale use of PMA soon disclosed some limitations to its application. Prompted by Seaman's (1950) report of mortalities among trout reated with PMA, Rodgers *et al.*, (1951) conducted tests that showed his compound to be toxic to larger fingerlings and older rainbow trout. rophylactic treatments can be made at biweekly periods rather than veekly and the concentration can be reduced to 1 p.p.m. in the treatment f fingerling sockeye salmon if the ratio between fish and the water in which they are reared is no less than 1:70 by weight (Burrows, 1951). The effect of temperature on the required frequency of treatments was not nvestigated.

An entirely new approach to the treatment of gill diseases has been made during the past decade. Since it is likely that very few of the chemicals, disinfectants or drugs with potential value were tested to date, we can anticipate new discoveries in the therapy and prophylaxis of gill diseases. The nutritional approach to the control of these diseases is also important.

FIN ROT

Little progress has been made in explaining the etiology of fin rot. Although in some cases undetermined bacteria were seen in the affected tissues and even isolated, no one has established their role in this disease (Davis, 1946). From trout with symptoms of fin rot, *H. piscium* and *A. salmonicida* were isolated along with other undetermined species in this laboratory. The early methods of treatment were limited to dips in copper sulfate (Wright, 1936) or treatment with potassium permanganate. Burrows (1941) reported satisfactory results with a prolonged treatment with formalin (1:4000). No attempt was made by the latter author to esta lish the cause of the disease, but since formalin produced good results c could suspect that protozoans may have played some role in the epizoo described by him. Chlorine treatment, even if promising, is so exacting th it must be carried out with great skill if it is not to be dangerous to t treated fish (Connell, 1937). Hewitt (1937) obtained good control of th disease by periodic disinfection of the troughs with chlorine (of cour the fish were removed during decontamination). A treatment with forma (1:2,000 for 1 hour) followed by a flush treatment with malachite gre was effective according to Eicher (1947). Phemerol, one of the quaterna ammonium disinfectants, was tested by McLaren, *et al.*, (1947). The b results were obtained by dipping the infected trout in an aqueous soluti of crystalline Phemerol (1:10,000) for 30 seconds; Prolonged treatmer were not tested. According to Wolf (1938), underfeeding predisposes t trout to fin rot; nipping by other fishes may also be of significance. Do doroff (1938) found that keeping fish in black containers may increa susceptibility to fin rot. Excessive illumination or ultraviolet radiation al may cause fin rot and other pathological changes (Lassleben, 1952). I provement was noticed when these predisposing conditions were remove

KIDNEY DISEASE

Kidney disease is common among salmon and trout on the West Coa (Earp, Ellis, and Ordal, 1953), and serious outbreaks occurred also some of the trout hatcheries in New England and New York State.[2] Th disease is caused by a microorganism which grows much better in th animal tissues than in bacteriological media. In observations made at th Leetown station the pathogen was seen in large numbers both extra- ar intracellular. It may be surmised from these facts that some relationsh may exist between the kidney-disease organism and the *Rickettsiales*. is not surprising, therefore, that, despite temporary arrest by sulfonamid of its multiplication in the tissues of fish infected by parenteral injectio the fish became sick and died when the therapy was discontinued. If, however, the disease was transmitted naturally through water, treatment wit this sulfonamide resulted in satisfactory although not complete prophylax (Rucker, *et al.*, 1951). It is of interest that in lymphogranuloma venereu infections in humans, certain sulfonamides are able to hold the infectio in check, but the virus within the cells is not killed (Bedson *et al.*, 1950

IMMUNIZATION

The effective and widespread use of chemotherapeutic drugs for th treatment of infectious diseases is of recent origin. In the past the mai weapons were sanitation, immunization, and serotherapy. Although man volumes were publised on immunity and immunization in diseases c humans and higher vertebrates, little work was done with fishes.

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[2] L. E. Wolf, personal communication.

The production of antibodies in fishes, which are poikilothermous animals, is affected by the temperature of the water. To mention just the more cent studies, Nybelin (1935) found that eels did not produce agglu-ins at a temperature of about 8° C. but immune sera of high titer were oduced at about 18° C. These results were confirmed by Snieszko *et al.* 938) with carp immunized against the infectious dropsy. Similar studies carp and trout were reported by Smith (1940). Further detailed data immunity of carp against this disease (Mann, 1939) indicated that the oduction of antibodies varied considerably according to the season of e year. This fact may explain the seasonal fluctuations in the outbreaks nd the severity of this infection. Some very interesting observations on he relationship between resistance to infection and disease, and the tem-erature in the poikilothermous animals were reported by Bisset (1946, 947). He wrote in the first paper ". . . that fish may become parasitised, ometimes heavily, by saprophytic water bacteria. Normally this causes ttle pathological effect, but under exceptional circumstances disease and ven death may result. There appears to exist, at low temperatures, a bal-nce between the aggressive action of the bacterium and the defensive owers of the host. Under such conditions the infected fish might be liken-d to a healthy carrier of a specific pathogenic organism. When the tem-perature is raised the balance is upset, probably by changes in the meta-bolic activity of both host and parasite. In these circumstances, if the fish s previously uninfected its defenses will be so greatly increased that it becomes completely resistant to infection. If, on the other hand, bacterial parasitism has already become established, the bacteria tend at first to in-crease and a proportion of the fish may die. In time, however, the surviving ish succeed, in many cases, in eliminating the bacteria from their bodies." This may explain many heavy mortalities among fishes in warm-water ponds during spring. Many of these infections are believed to be caused by pseudomonads, chiefly *Aeromonas liquefaciens* (*Pseudomonas punctata*). Since infections caused by pseudomonads usually respond well to antibiotics like chloramphenicol, terramycin and aureomycin, one could try treating infections in valuable brood stock fishes with antibiotics during the period of raising temperature of water in the spring, until the temperature becomes high enough for the production of specific antibodies.

Oral administration of antigen (Thomson *et al.*, 1948) offers a simple but not highly effective method of immunization. Although Duff (1942) found oral immunization of cutthroat trout against natural infection promising, the protective value is doubtful particularly against intramuscular injection (Snieszko and Friddle, 1949). The problem may be worth reinvestigation since Duff (1937) indicated that *A. salmonicida* dissociates into various colonial types in phenol and lithium chloride broth. Duff found an opaque, convex, cream-colored variant which he termed a rough (R) type which was stable on prolonged subculture. What is more important, this variant was also non-pathogenic! The present author feels that such a variant offers an exceptionally fine approach to the immunization of trout by living, attenuated cultures. The possibility of establishing a stable, living, non-pathogenic variant of *A. salmonicida* in a given fis population appears promising, since the carrier state is known in furunculosis, and little or no leukocytic response is obtained in this disease. Th problem merits investigation. Duff's work also is indicative of the relativ ease with which *A. salmonicida* can mutate.

Toxicity of Drugs Used in the Treatment of Bacterial Fish Diseases

The ideal chemotherapeutic drug should be invariably toxic to th pathogenic microorganism but entirely harmless to the host. Since suc drugs are not yet known, one has to be satisfied with substances that hav the widest possible margin of safety between the effective dosages and thei toxic levels. This discussion will mention only those materials that ar used with satisfactory results in the treatment and prevention of bacteria fish diseases.

Sulfonamides and antibiotics are the best antibacterial drugs. Toxicit of the former to fishes was first investigated by Litchfield (1939) Parenterally introduced sulfanilamide was found to be toxic to Atlanti spiny dogfish (*Squalus acanthias*) when the blood level of this drug wa above 5 milligrams per 100 milliliters, but acute symptoms and deat occurred at the blood levels of 10 to 12 milligrams. In tests with variou animals, sulfanilamide was about 15 times more toxic to fish than to frog and about 4 times as toxic as to chickens. Attempts to produce anemia i fish were unsuccessful even after 7 days of treatment. Gutsell and Snieszk (1949b) determined the effect of sulfamerazine on fingerling trout of thre species treated at the water temperature of 12° to 13° C. The growth o rainbow trout was not affected even after 40 days of continuous treatment. The growth rate of brook trout was reduced in proportion to the dosage, but no gross toxic effects were noticed. The growth of brown trout was completely arrested during treatment by dosage rates of 5 to 15 grams per 100 pounds of fish per day. Brown trout suffered no mortalities that could be attributed to the toxic effect of the drug, and the hemoglobin content was significantly higher (analysis of variance) in the treated fish. In brown trout and brook trout treated continuously at a constant dosage rate, the concentration of sulfamerazine increased in the tissues for about 10 days and afterwards started to decline, whereas in the rainbow trout, the tissue level of the drug rose slowly but steadily during the 3 weeks of treatment (Snieszko and Friddle, 1951, 1952). Johnson and Brice (1953) observed that sulfamerazine was toxic to fingerling silver salmon 1 to 3 grams in weight treated at about the same temperature (10° to 12° C). Somewhat larger salmon (more than 6 grams) kept in warmer water were not affected. It is not known whether the age of fish, the temperature of the water, or both, brought about this difference. Litchfield (1939) found that sulfanilamide was more toxic to frogs at 5° than at 15° C. Additional observations on the effect of sulfanilamide on fish (Snieszko and Friddle, 1951) have shown that while the uptake of this

g through the intestinal tract was good, the tissue level dropped much
ter, despite continuous treatment, than that of any other sulfonamides
ted.

Observations not yet tested experimentally, give cause to suspect that
olonged treatment with sulfonamides may impair reproduction in trout.
riflavine (Pickford, 1952), a disinfectant used in the treatment of
uarium fishes and in the disinfection of trout eggs, slowed the growth of
ndulus heteroclitus and retarded development of the testes. The latter
ect could be prevented by the addition of *Daphnia* to the diet.

The new external disinfectants used in the treatment of gill disease and
ternal parasitic infestations are also toxic to fishes. Rucker, Johnson, and
dal (1949) found that the mixture of alkyl-dimethyl-benzyl-ammonium
lorides (sold under the trade name "Roccal") in which the homologues
ntained 10, 12, and 14 carbon atoms in the alkyl chain had the strongest
ctericidal properties toward *Chondrococcus columnaris* and the least
xicity to fish. Homologues containing 16 and 18 carbon atoms were more
xic to fish than to the bacteria. They determined also that the substitution
the benzyl radical for a methyl group on the central nitrogen atom pro-
undly influenced the relative toxicity to fish and bacteria.

Pyridylmercuric acetate (PMA, technical) which is now widely used
r the treatment of gill diseases and external parasitic infections, has been
und to be non-toxic at various water temperatures up to the age of
year in the sockeye, chinook and coho salmon, as well as brook trout
nd rainbow trout (Burrows and Palmer, 1949). This chemical is toxic,
owever, to rainbow trout (Rodgers *et al.*, 1951). In experiments con-
ucted by these authors brook trout and brown trout were not affected,
nd in rainbow trout less than 3 inches long, the toxic effect was limited
o loss of appetite for about 1 day following the treatment. According to
oster and Olson (1951), however, it was frequently fatal to rainbow
rout particularly at higher temperatures. Wolf (1951b) confirmed these
esults and found that PMA was also non-toxic to Atlantic salmon and
ake trout. Rucker and Whipple (1951) also have found PMA toxic to
-inch rainbow trout. Malachite green was found by the same authors to
e slightly toxic to small rainbow trout and lethal to 3-inch sockeye sal-
non. The explanation of the nature of the specific toxicity of PMA to
arger rainbow trout would be most interesting.

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VIRUS DISEASES OF FISH

STANLEY W. WATSON

U. S. Department of the Interior, Fish and Wildlife Service
University of Washington, Seattle, Washington

ABSTRACT

Viruses are probably the cause of a wide spectrum of fish diseases. Although relatively few virus diseases of fish are known today, some of the diseases of unknown etiology, as well as some diseases presently accepted as due to bacteria, protozoa, fungi or nutritional deficiencies, possibly will be recognized eventually as virus diseases.

Some viruses may induce proliferative tissue changes whereas others may cause degenerative change. Although several diseases of a proliferative nature have been reported to be of virus origin, positive experimental evidence for the transmission of a virus from one fish to another, has been presented for only lymphocystis.

The degenerative or non-neoplastic diseases of possible virus origin give the fish-culturist the most concern because of the severe mortalities resulting from infection. Epizootics of this nature have been reported in carp (*Cyprinus carpio*) and rainbow trout (*Salmo gairdneri*) in Europe, in acara (*Geophagus brasiliensis*) in South America, in kokanee, (*Oncorhynchus nerka kennerlyi*) and in sockeye salmon (*Oncorhynchus nerka nerka*) in the State of Washington. It has been demonstrated that each epizootic was caused by an infectious filterable agent, probably a virus.

INTRODUCTION

Contagious diseases of fish have created problems since the first attempt by man to rear fish in hatcheries. With the development of microbiology, contagious diseases of fish have been attributed to protozoa, fungi, bacteria and larger organisms (*e.g.*, trematodes). Other diseases, such as fish pox (Roegner-Aust and Schleich, 1951), are well known, but the nature of the etiological agents has remained in question. Recently some of these diseases have been shown to be caused by viruses.

Unfortunately, viruses do not lend themselves to direct investigation as easily as do most of the larger microorganisms. Unlike most bacteria, they cannot be grown *in vitro* except in tissue cultures, since they are obligate intracellular parasites. Likewise, viruses cannot be seen with the ordinary light microscope because of their small size. Thus, positive proof that a disease is of virus origin is difficult to obtain. To establish a virus as an etiological agent some of the following arbitrary criteria have been used in such textbooks on virus as that of Rivers (1948):

1. The primary requisites are that the etiological agent passes through bacteria-tight filters, that the agent is infectious, and that the agent is transmissible in series in the experimental animal.
2. The absence of microorganisms other than viruses in exudates and diseased tissues constitutes evidence, but not proof, that a disease may be caused by a virus.

There may be present either secondary invaders or such microorganisms, spirochae and rickettsia, which are difficult to demonstrate with ordinary techniques.

3. The presence of inclusion bodies in some diseases (as Negri bodies in rabi offers a highly reliable indication of a virus infection. Recognition of virus inclusio requires experience, since various intracellular structures (*e.g.*, fluid vacuoles, glycog droplets, and large eosinophilic nuclei) may be mistaken for inclusion bodies (Pinke ton, 1952). There are, however, many virus diseases in which no inclusion bodies ha been demonstrated.

4. Eamination under an electron microscope is useful for the demonstration of vir particles in diseased tissues or exudates, but it should not be used as a sole basis f diagnosis since protein and other molecules may be confused with virus particles.

5. An infectious agent causing neoplasia or hyperplasia is likely to be a viru Pinkerton (1952) stated that, "Other than intact tumor cells, the only transmissib agents which are known to cause neoplasia are certain filterable agents, generally a cepted as viruses, which induce tumors in lower animals and plants."

This paper is intended as a review and evaluation of the literature o virus diseases of fish. The review was prompted by an uncontrollab virus disease in sockeye salmon being raised in hatcheries in the State (Washington (Rucker, *et al.*, 1953). Some work which is being done by th writer on a virus disease of sockeye salmon will also be reported.

NEOPLASTIC AND HYPERPLASTIC DISEASES

Fish diseases characterized by proliferative tissue changes are numerou but evidence that they are caused by viruses is largely circumstantial. Onl a brief discussion of neoplastic and hyperplastic diseases will be given sinc Nigrelli (1952) recently reviewed the subject.

Fish Pox.—Fish pox is one of the earliest diseases of fish reporte in which proliferative changes are involved. This disease, (according t Roegner-Aust, 1953) was described as early as 1563 by the naturalis Gessner and is still prevalent in Europe, (Roegner-Aust and Schleich 1951). Although the disease does not cause severe mortalities, rather larg economic losses are suffered because afflicted fish are not marketable.

Fish pox produces whitish opaque spots on a thickened epidermis o carp and related cyprinids. The hyperplasia of the epidermis is microscopi cally indistinguishable from a true neoplasm; however, it may spontaneously regress and disappear (Schlumberger and Lucké, 1948).

Epizootiological evidence indicates that fish pox is an infectious disease although transmission experiments have not been successful. The presence of inclusion bodies in infected cells, demonstrated by Loewenthal (according to Nigrelli, 1952), Plehn (1910) and others, indicated the possibility that a virus was the infectious agent. Roegner-Aust and Schleich (1951) have recently studied these inclusion bodies with an electron microscope and found that they contain granules which were interpreted as elementary bodies. Thus, subject to additional investigation this disease is tentatively designated as one of virus origin.

Lymphocystis.—Lymphocystis is a disease in which the infected cells undergo hypertrophy. Evidence indicates that this disease is of virus origin. Lymphocystis was described originally in a European flounder (*Pleuronectes flesus* and *P. platessa*) in 1874 by Lowe (according to Nigrelli and Smith, 39). It was first reported in the United States in the walleye, by Mavor d Feinberg (1918). More recently it has been found in a wide variety of th fresh- and salt-water fish including the walleye (*Stizostedion vitreum treum*), the blue angelfish (*Angelichthys isabelita*), the hogfish (*Lachlaimus maximus*), the orange filefish (*Aleutera* [*Ceratacanthus*] *hoepfi*), the killifish (*Fundulus heteroclitus*), and others (Smith and igrelli, 1937; Weissenberg, Nigrelli, and Smith, 1937; Weissenberg, 1938 d 1939). The disease is chronic, lasting 1 to 3 years. High mortalities ave not been reported, but in Saginaw Bay infected walleyes have been ound to weigh 5½ to 6½ percent less than sound fish of the same length.[1]

Lymphocystis is characterized by the development of small, irregular, olitary or confluent nodules, often distributed laterally on the body or on e fins. Microscopic examination reveals a gigantic hypertrophy of osteolasts and fibroblasts as well as a peculiar transformation of infected cells. he so-called "lymphocystis cell" reaches a diameter of 5 millimeters or ore and is surrounded by a thick, transparent membrane. Conspicuous tructures which have been interpreted as inclusion bodies have been seen n these infected cells by Weissenberg, Nigrelli, and Smith (1937), Nigrelli nd Smith (1939), Weissenberg (1949 and 1951a), and others.

Specific granules in the outer layers of the inclusion bodies have also een demonstrated and interpreted as elementary bodies (Weissenberg, 949 and 1951a; Alexandrowicz, 1951). Weissenberg (1951a) and others ave followed the development of these inclusion bodies and granules; the vidence indicates that they are of possible virus origin. More conclusive vidence suggesting a virus as the etiological agent was found when Weissenberg (1951b) transmitted the disease experimentally to healthy fish with bacteria-free filtered material from an infected fish.

Other diseases of a neoplastic nature considered to be infectious, and therefore, probably of a virus origin, are fish papillomas and certain lymphosarcomas (Nigrelli, 1952).

Non-neoplastic Diseases

There are undoubtedly many virus diseases of fish in which the primary effect is destruction and necrosis of the host cells. Such diseases include the European infectious dropsy of carp, the South American disease of acara, the European kidney disease of rainbow trout, and the disease of sockeye salmon in the State of Washington.

Infectious dropsy of carp.—Infectious dropsy has been known for a number of years in carp. Pestilent outbreaks of the disease with resultant severe mortalities and economic losses have occurred in Europe since the eighteenth century (Layman, 1949). Severe epizootics occurred in Germany in 1928 and spread to Holland, Scandinavia, Czechoslovakia, and Poland. In 1936 and 1937 the number of epizootics of infectious dropsy decreased gradually. Epizootics in Russia declined from 1938 to 1941, but the disease again resumed epizootic proportions in 1942 and 1943.

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[1] Dr. Ralph Hile, private communication, 1953.

Some fish-culturists were forced to abandon the culture of carp for a ti and to rear other kinds of fish to avoid mortality rates of 60 percent more (Layman, 1949).

Originally, Schäperclaus thought that *Pseudomonas punctata,* the et ological agent in infectious dropsy (Nigrelli, 1952), but in 1937 Schäpe claus (according to Roegner-Aust, 1953) suggested the possibility of a vir as the primary agent. Bacteria-free filtrates of coelomic fluid of disease carp were infectious, whereas bacteria-free filtrates of coelomic fluid fro fish inoculated experimentally with *P. punctata* were not infectious. Schäpe claus (1953), now seems to discount the possibility of a virus as the eti logical agent, since he was able to demonstrate that exotoxins from *P. pun tata,* inoculated into carp would cause the symptoms of dropsy. Dombrov ski (1953) recently reviewed the question "Bacterium oder Virus?" H expressed the firm belief that *P. punctata* rather than a virus was the eti logical agent in infectious dropsy.

Other workers, however, have presented fairly convincing evidence th a virus, if not the primary etiological agent, at least contributes to th symptoms of infectious dropsy. This work has included filtration and ag glutination experiments, cytological studies, and differential blood counts b Layman (1949) and electron-microscope studies by Roegner-Aust, Brunne and Jaxtheimer (1950), Roegner-Aust, and Schleich (1951), and Roegne Aust (1953).

From my review of the literature I believe that additional work, inclu ing serial transfers of bacteria-free suspensions of infected material as a inoculum, is needed before the etiological agent of infectious dropsy can b established with certainty.

European kidney disease.—Schäperclaus (1941) described an infectio kidney disease among rainbow trout in European hatcheries that may b of virus origin. The disease was reported to cause 30- to 60-percent mo tality in rainbow stocks. During the course of the disease, the only noticeable external symptom was the dark color of some fish. Autopsy reveale that the kidney was swollen, corrugated, brown, and mottled with whit Schäperclaus was not able to demonstrate the presence of bacteria in diseased tissue, but he showed that healthy fish which were inoculated with bacteria-free filtrate of diseased tissue developed the original symptoms o the disease.

Similar, if not identical, kidney diseases have been described by Beldin and Merrill (1935) in brook trout (*Salvelinus fontinalis*) and rainbo trout at hatcheries in Massachusetts, by Wales[2] in brook, rainbow an brown trout (*Salmo trutta*) at hatcheries in California, and by Earp, Ellis and Ordal (1953), in chinook salmon (*Oncorhynchus tshawytscha*), coh salmon (*O. kisutch*) and sockeye salmon at hatcheries in the State of Washington. Earp was able to demonstrate a gram-positive diplo-bacillus as th causative agent and was able to obtain growth of this microorganism on non-living culture medium after prolonged incubation. Earp could no demonstrate that the infectious agent was filterable. Because of the patho

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[2] **J. H. Wales, private communication.**

gical similarity among all of the described kidney diseases, additional
vestigations are needed to determine whether the same etiological agent
involved.

South American virus disease.—Description of a virus infection called
ryo-icthyozoose" has been reported in economically important river
h in the state of Sao Paulo, Brazil, by Pacheco and Guimaraes (1933) and
agarinos and Pacheco (1934). Healthy fish contracted the disease when
posed to contaminated water which had been passed through a bacteria-
ght filter. The infective powers of this virus disappeared at temperatures
eater than 16° C. Macroscopic examination of diseased fish revealed
rculatory congestion at the base of the fins, some posture modifications,
ale gills and viscera, and mucus in the mouth and stomach. The gall blad-
er appeared as a dark-red, membranous sac containing a sticky, amber-
olored bile.

Magarinos and Pacheco (1934) experimentally infected acara with this
irus. Microscopic examination of the buccal-cavity epithelium showed
tomatitis complicated by eosinophilic cytoplasmic inclusions and swollen
uclei. There was no evidence of hyperplasia or general increase in cell size.

Diseases of sockeye salmon.—Severe mortalities have occurred in hatch-
ry-reared sockeye salmon fry and fingerlings in the State of Washington
or the past several years (Rucker *et al.*, 1953). Several micro-organisms,
ncluding *Pseudomonas hydrophila* and the gram-positive diplobacillus of
idney disease (Earp, Ellis and Ordal, 1953) have been suspected as the
tiological agents in some of the epizootics. No conclusive evidence impli-
ating any particular microorganism was found prior to 1951.

An epizootic of possible virus origin occurred in 1951 in the federal
atchery at Leavenworth, Washington. This disease affected fingerlings of
oth the sockeye salmon and kokanee, but did not affect fingerlings of
he chinook salmon, coho salmon, or cutthroat trout (*Salmo clarki clarki*).

This epizootic was characterized by its explosive nature, by severe mor-
talities, and by the failure of therapeutic measures to control or alleviate
the disease. A small percentage of the afflicted fish developed retracted
heads and spinal deformities resembling scoliosis and lordosis.

When the disease in sockeye salmon was recognized in 1951, it was confined to 6 of 102 hatchery troughs. The epizootic started about March 20, 1951, and a 33.5 percent mortality had occurred in the 6 troughs by April 19. By the third week of May, nearly all the fish were dead in the infected troughs.

The epizootic among the kokanees at the Leavenworth station occurred in late June and early July of 1951. This disease was more general in the hatchery, but all troughs were not infected. The cumulative mortality attributed to this disease reached 39.6 percent of all hatchery stock by October.

A similar epizootic occurred in sockeye salmon fingerlings at the same hatchery in June 1952. All 11 ponds, each stocked with approximately 200,000 sockeye salmon, became infected during June.

Mortality in sockeye salmon ponds is usually about 0.01 percent per day under normal conditions, but rose to 1 percent per day in 6 to 9 days aft infection. The daily mortalities in individual ponds then rose to a maximu of 28 to 32 percent a day during the next 12 to 16 days. In 16 to days after the onset of infection the cumulative mortality had risen to percent. In another 11 days 90 percent of the fish were dead. The mortali then decreased gradually to 0.02 percent per day. In the latter part September the mortalities rose slightly from 0.07 to 0.9 percent per da and remained nearly constant until the latter part of October. By la September approximately 145,000 survivors remained from the origin population of 2,872,000 fish (Fig. 1).

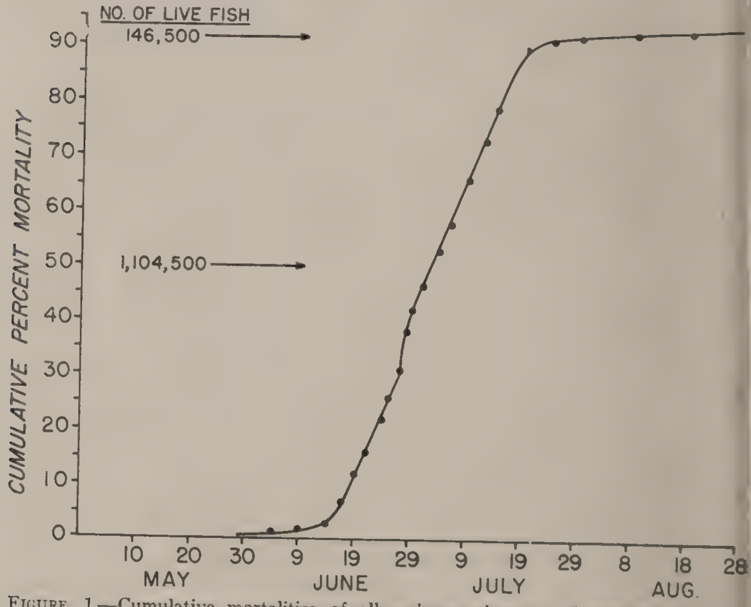

FIGURE 1.—Cumulative mortalities of all sockeye salmon at Leavenworth during the epizootic in 1952.

Twelve similar epizootics have occurred in the last 3 years in five of the seven hatcheries which have reared sockeye salmon in the State of Washington.

The pathology in all epizootics was similar or identical. Diseased fish were lethargic; hemorrhagic areas appeared at the base of the fins and in the isthmus; the stomach was distended and often filled with a milky fluid; the intestines were reddened and contained a straw-colored, watery fluid often tinged with blood; hyperemic areas were present in the air bladder, peritoneum, and fat; and spinal deformities developed among some of the fish that had survived the early stages of the epizootic.

No parasite was demonstrated in diseased fish nor were bacteria isolated at could be shown to cause the disease. Furthermore, fish inoculated th bacteria-free filtrates of moribund fish contracted the disease. The idence obtained from our studies indicated that the disease was caused a virus.

Prevention and Control

The prevention and control of virus diseases of fish presents a serious oblem, since present-day chemotherapy is not efficacious. The measures sed to prevent and control virus diseases in man have included immuniza-on, the use of specific antisera, sanitation, elimination of vectors, and uarantine of infected individuals. Obviously, all of these methods are not easible in the control of virus diseases in fish.

The only successful measures for prevention and control of virus diseases f fish have been the quarantine of stocks which were either infected or xposed to infection (Layman, 1949; Rucker *et al.*, 1953). The breeding f immune stocks of fish has also been successful (Layman, 1949). Lay-nan selected carp for brood stock which had survived infectious dropsy lisease and thus were thought to have a natural immunity. Mortalities were educed from 60 percent to 4 or 5 percent after several years of selective reeding with this stock.

It is important in the prevention of a virus disease to determine the riginal source of infection. Food, water, animal vectors, and eggs from infected adults are possibilities. Snieszko (1953) has outlined measures to control virus diseases if they originate from the above sources.

Suggestive, but not conclusive, evidence by Roegner-Aust, Brunner and Jaxtheimer (1950) suggested the possibility that the virus of infectious dropsy disease of carp was transmitted through apparently healthy eggs. This possibility was considered in the Washington hatchery epizootics. Sockeye salmon became infected at one hatchery, but not at another hatchery, although the original source of eggs was the same for both hatcheries. This evidence tends to throw doubt on the possibility that eggs were responsible for the introduction of the disease in the Washington hatchery population. Likewise, epizootics occurred at hatcheries widely separated geographically and with different sources of water and food. All troughs in a given hatchery were not infected concomitantly, nor were adjacent ponds or troughs necessarily infected simultaneously. Wunder and Dombrowski (1951) reported on the transmission of infectious dropsy disease of carp by parasitic copepods and leeches. Attempts have been made to isolate the Washington hatchery virus directly from possible animal vectors as well as from food, water, eggs, and plant vectors. All experiments of this type thus far have been negative, but evidence does not preclude the presence of a virus in one or all of these sources. It must be recognized that the probability is slight of isolating a virus directly from these sources if the number of virus particles is small or irregularly distributed.

Hatchery records for the periods of epizootics showed that all diseased

TABLE 1.—*Synopsis of knowledge of virus diseases of fish*

Item	Virus disease							
	Lymphocystis	Fish pox	Lymphosarcoma	Papilloma	Infectious dropsy of carp	Disease in acara	Disease in sockeye salmon	European kidney disease
Contagious from epizootiological evidence	+	+	+	+	+	+	+	+
Experimentally transmitted with serial transfers	−	−	−	−	−	−	+	−
Filterable agent experimentally infectious	+	−	−	−	+	+	+	+
Inclusion bodies demonstrated	+	+	−	−	−	+	−	−
Demonstrated with electron microscope	−	+	−	−	+	−	−	−
Primarily proliferative	+	+	+	+	−	−	−	−
Primarily degenerative	−	−	−	−	+	+	+	+
Chronic	+	+	+	+	+	−	−	+
Acute	−	−	−	−	+	+	+	−

h had been fed a similar fish-product diet. Hatchery fish which received
diet containing no fish products did not acquire the symptoms of the
rus disease unless experimentally exposed to the disease. Thus, the prac-
e of feeding untreated, raw fish products to hatchery-reared fish must
regarded with suspicion. This attitude was also recently expressed
Snieszko (1953).

Current experimental evidence gives little cause to believe that hatchery
rsonnel spread the disease from trough to trough if sanitary precautions
e enforced. Only a few fish in a given trough or pond seem to be in-
cted directly from the original source, but these few diseased fish appar-
ntly infect the remaining healthy population with great rapidity. It is
kely that by the time the disease is recognized in a trough, most of the
opulation is infected.

Immunological, chemotherapeutical, and other remedial treatments are
f value and should be investigated thoroughly. However, some of these
nethods, by their very nature can be evaluated only after several years of
nvestigation. Immediate control of the epizootic in sockeye salmon appears
o depend largely upon the prevention of the disease by the elimination of
he original source of the virus.

Preventive and control measures for virus diseases of fish must await an
ntensive study of the diseases and their mode of transmission. As yet,
evidence that viruses are agents causing many fish diseases is not conclusive (Table 1). Fundamental research is necessary to detect the source of infection, to define the manner by which the disease is transmitted, and to describe the pathological changes in infected fish.

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DEVELOPMENT OF DISEASE-RESISTANT STRAINS OF FISH

LOUIS E. WOLF

New York State Conservation Department
Rome, New York

ABSTRACT

Some of the achievements in selective breeding of animals for resistance to diseases are discussed. The literature on disease resistance among strains of trout within a species is reviewed. The known mechanisms of disease resistance are discussed in relation to the problem of creating maximum resistance through selective breeding.

A brief report is made on the results of the first 11 months of operation of a Dingell-Johnson project of breeding brook and brown trout for resistance to ulcer disease and furunculosis.

The variability of animal and plant species and the use of selective breeding to stabilize variants into widely different varieties and strains is well known. Outstanding examples of this process occur in fish as seen in the many varieties of goldfish which have been established by Japanese breeders, and in the profusion of color- and fin-forms which have been produced in some species of tropical fish.

This paper is confined to only one aspect of selective breeding, namely, breeding for resistance to disease. Embody and Hayford (1925) (see also Hayford and Embody, 1930) reported on a breeding program carried on for a number of years at the Hackettstown, New Jersey, hatchery. Davis (1946) briefly summarized breeding work done in several hatcheries where the emphasis, as in the work of Embody and Hayford, was not primarily on disease resistance. The writer knows of no sustained effort which has been made to improve fish in this respect. Scarcity of published reports, however, does not mean that nothing has been accomplished. A certain amount of selection is, without doubt, exercised by many trout-culturists at spawning time, and this, together with the natural elimination of the most susceptible individual fish before they reach spawning age, undoubtedly has resulted in greater disease resistance in hatchery stock than is present in wild stock.

The absence, up to now, of any sustained program of selective breeding should not be regarded as indicating a lack of interest on the part of fish-culturists. Such breeding of trout requires special facilities not available at a regular production hatchery, and these facilities are costly to construct. Wright (1951-52) has described excellently these difficulties, and has summarized the problem from a geneticist's view point.

Breeding for disease resistance has not, in general, been as extensive for animals as for plants. This does not reflect upon the suitability of animals for such genetic improvement, but rather has resulted from the ease with ich large domesticated animals can be treated individually. Veterinary ence has advanced rapidly, and medical treatment of valuable animals s been so successful that there has been little demand for genetic im- ovement in resistance to disease. The fear is now expressed by veteri- rians, as well as by physicians, that the very effectiveness of modern medi- ne may reduce natural or genetic disease resistance to a point where new ngers are created.

There has, of course, been a very widespread application of genetic ethods in breeding the larger domesticated animals for improved per- rmance along certain lines, or for greater conformity to arbitrarily defined eed characteristics. Efforts to impove the animal have been chiefly along at might be called "negative" lines, *i.e.*, to breed *out* certain undesirable aits or familial defects which have appeared from time to time. Among ese might be mentioned hemophilia in dogs, cryptorchidism in pigs, and arfism in several breeds of cattle, particularly Herefords about which we ear so much at present. Some positive work has been done in California establish resistance to brucellosis in swine.

It is quite certain that genetic resistance to disease exists in certain reeds, or individuals, of our larger domesticated animals. A striking il- stration occurred in sheep in Iceland. The native sheep had been an iso- ated strain for many hundreds of years. These sheep were rather mall, and there was frequent agitation to "improve" them through the portation of larger European breeds. Larger sheep were finally imported rom Germany. The introduced animals, which appeared free from disease, roved to be carriers of infection for which the Icelandic sheep had no esistance. The result was a decimation of the native flocks from diseases hich were so rare in Germany as to be almost unknown to German veterin- rians. While the German sheep were disease resistant, they proved to be oorly adapted to the climate and feeding practices of Iceland, so that no enefit resulted from their importation.

With smaller domesticated animals and with laboratory animals, more as been done to breed for resistance to infection, and one gets a clear ndication of what is possible in this field. As the individual value of an animal decreases and the numbers commonly dealt with increase, it becomes more important to use mass methods in handling them. With chickens, for instance, chemotherapy is used for entire flocks and mortality is further controlled by culling. The chicken is, however, well suited for breeding for disease resistance.

Roberts and Card (1935) selected chickens for resistance to pullorum disease. Their experiment continued for 10 years, and resulted in establishing strains highly resistant to *Salmonella pullorum*. They found this resistance to be inheritable, and dominant to susceptibility, with probably more than one pair of genes involved. Crosses between two resistant strains resulted in progeny with greater resistance than either parent strain. The blood of a resistant strain had a higher erythrocytic count and lower leucocyte count than that of the susceptible line.

Hutt and Cole (1947), by selective breeding over a period of 12 years, developed two strains of white leghorns which were highly resistant and on strain which was susceptible to lymphomatosis, a virus disease. When th two resistant strains were crossed, the progeny were less resistant than eithe parent strain. This would indicate the resistance in the two trains to be du to different pairs of genes, and that resistance was also not completel dominant over susceptibility.

Cole (1950) later tested the three strains for resistance to a totally different disease, bluecomb, and found that the two lymphomatosis-resistan strains differed greatly in resistance to bluecomb, and that the lymphomatosis-susceptible strain was apparently immune to the malady. This illustrate the concept, now generally accepted, that there is no such thing as hereditary, general resistance to all infections, but that in all cases genetic resistance is specific to one particular disease.

A good general account of what is known of genetic aspects of mortalit in the fowl is contained in "The Genetics of the Fowl," by F. B. Hut (1949). Parts of this book might well be read by anyone interested in th breeding of disease resistant fish. The author's arguments for a genetic attack on the problem of disease in chickens apply with equal force to disease in trout.

Among laboratory animals more work has been done with mice than wit any other form. Many strains have been bred resistant to a number of bacterial infections. A comprehensive summary of the genetic work with mic has been made by Grüneberg (1952), who includes a case of inherite difference in susceptibility to infection with a tapeworm. Even the hone bee has been investigated, and a strain has been found which, because of it superior housekeeping, is less subject to foulbrood. The passion for cleanliness is, in this case, hereditary. There have been a few published report on differences in disease resistance among strains of trout. Wales and Evin (1937) presented data for three strains of rainbow trout which showed differences in susceptibility to mechanical irritation of gills by suspende particles in the water. Davis (1946) mentioned differences in mortalities in various strains of hatchery-reared brook trout. The writer (Wolf, 1941) published a brief note regarding differences in resistance to ulcer disease in six strains of brook trout, and reported (Wolf, 1942) that two strains of rainbow trout differed markedly in showing injury from lack of vitamin B_1 in the diet. Additional evidence that trout are well adapted for genetic selection appears in a later paragraph.

Establishing disease-resistant strains of any of the domesticated animals is a worthy achievement, and is for the fish-culturist a sufficient goal. Grüneberg (1952) has appropriately stated that, "The discovery that resistance or susceptibility is genetic remains barred unless the physiological channels are known by means of which differences are brought about. Once these mechanisms are clear, the way is open for therapeutic measures." Many current investigations are concerned with the mechanisms of genetic resistance to disease.

Nothing like a complete list of the factors within the host which affect resistance to disease could be made at present. New discoveries are being ade as a result of great activity in such fields as nutrition, physiology, and ochemistry. Some of the factors listed below have been mentioned in the erature but have never been subjected to critical experimentation; others ve been studied in some detail; all probably have a genetic basis.

1. Barrier action of the skin and mucus membranes. In the case of fish the mucus itself is commonly supposed to have a protective function against invasion by infective agents.
2. Destruction of foreign organisms by gastric and intestinal secretions.
3. Number and activity of blood leucocytes.
4. Number of erythrocytes in blood.
5. Ability of macrophages to digest phagocytized bacteria.
6. Bactericidal properties of blood serum.
7. Presence of natural antitoxins.
8. Ability to form antibodies.
9. pH of blood.
10. Detoxifying activity of the liver.
11. Efficiency in absorption and metabolism of certain vitamins, or other food-factors, involved in any of the above agencies.

The complications in the relationships between resistance factors are indicated in the work of Weir (1949) and Weir, Cooper, and Clark (1953) who found that in certain strains of mice selected for resistance to *Salmonella typhimurium* the leucocyte count and blood pH were positively correlated with resistance. When, however, strains were selected on the basis of leucocyte count and pH of blood, and were then subjected to infection with the same organism, no positive correlation was found.

One reason for listing some of the host factors which may affect genetic resistance to disease is to emphasize that in any one case many mechanisms may be, and usually are, implicated. If only a single character, depending on a single pair of genes, were involved, it would be a simple matter to establish a pure, or homozygous, strain, and this strain could be maintained pure and undefiled to transmit its characteristics to all its progeny. But where many factors operate, and probably most of them depend on several pairs of genes, it becomes almost impossible to establish a pure line. Thus, while it is fairly certain that any intelligent program of breeding for resistance to disease should accomplish something, it is also fairly certain that such a program should continue as long as the art of fish culture is practiced. Reversion is likely to occur when selection practices are abandoned.

No absolute resistance or immunity to any disease natural to a species has yet been established through genetic selection. Resistance has been greatly increased, but never yet made absolute. One reason for this may lie in the failure to use at all times the most virulent strains of organisms for challenging the breed lines, but another reason lies in the multiplicity of mechanisms and of genes involved in resistance to infection.

A selective breeding project on trout has been in progress at Rome, New York, for one year. While the fish have not yet reached maturity some in-

TABLE 1.—*Percentage monthly mortality of brown trout, from ulcer disease and furunculosis*

Month	Mean water temperature (° F.)	Lot							Average
		A	B	C	D	E	F	G	
Sept.	58.8	0.1	0.3	0.9	0.0	0.1	0.5	35.6	[1]0.3
Oct.	52.2	2.8	1.2	4.6	0.9	1.1	3.1	1.1	2.1
Nov.	48.4	0.4	0.5	0.2	0.3	0.5	0.0	0.2	0.3
Dec.	38.4	0.2	0.3	0.1	0.2	0.0	0.0	0.0	0.1
Jan.	36.7	0.2	0.4	1.0	0.3	0.4	0.0	0.0	0.3
Feb.	37.5	0.1	1.2	0.9	0.8	1.8	0.0	0.0	0.7
Mar.	38.7	0.0	4.8	0.9	1.1	0.7	0.0	0.1	1.1
Apr.	45.0	0.4	8.4	0.4	2.4	0.4	0.0	0.2	1.7
May	49.1	1.0	11.1	0.9	1.4	5.6	0.0	0.9	3.0
June	56.3	17.5	25.0	47.1	10.2	41.6	14.3	7.0	23.2
July	59.6	37.1	47.7	29.0	27.6	27.8	22.2	23.6	30.7
Total	....	50.8	61.7	65.8	39.7	60.2	35.7	55.4	....

[1] Lot G omitted from average for September because mortality was chiefly from gill disease

TABLE 2.—*Percentage monthly mortality of brook trout, from ulcer disease and furunculosis*

Month	Lot											Average
	A	B[2]	C[2]	D	E	F	G	H	I	J	K	
Sept.	4.9	1.2	0.3	17.0	1.0	0.1	0.0	1.0	0.0	0.0	0.0	2.3
Oct.	11.2	70.5	94.9	77.6	0.0	2.3	6.3	24.0	0.7	5.1	4.7	27.0
Nov.	0.5	16.9	32.8	2.5	0.0	50.5	27.9	26.6	2.9	1.2	11.6	15.8
Dec.	0.1	2.4	10.3	1.5	0.0	18.3	3.8	4.7	6.7	0.7	6.7	5.0
Jan.	0.1	1.6	2.9	0.5	0.0	7.0	3.3	3.2	8.3	0.6	6.5	3.1
Feb.	0.0	1.3	0.0	1.6	0.0	2.4	1.4	1.6	12.2	0.3	7.7	2.6
Mar.	0.2	0.0	0.0	1.6	0.0	3.0	1.6	0.7	12.7	1.6	8.8	2.7
Apr.	0.8	0.4	8.8	2.7	0.0	2.3	0.5	0.7	19.6	3.7	16.5	5.1
May	0.8	0.0	3.2	4.4	0.0	23.5	1.3	3.8	20.5	5.5	15.5	7.1
June	1.7	10.1	6.7	9.2	0.5	64.8	32.0	72.9	41.7	36.9	28.8	27.7
July	6.3	58.0	0.0	35.0	3.9	95.1	25.9	77.9	37.1	50.5	21.7	41.1
Total	24.1	91.5	97.8	90.6	5.3	99.6	69.8	97.2	85.2	74.2	75.6	....

[1] Water temperatures same as in Table 1

[2] Lots B and C were same strain, but from different hatcheries

formation is pertinent. During September, 1952, 11 lots of brook trou (*Salvelinus fontinalis*) and 7 lots of brown trout (*Salmo trutta*) fingerling were collected from all the northeastern states. With a single exception a lots were from broodstock which had existed as separate, inbred strains fo at least 8 years—though in most cases the lines ran back much longer.

These fish have been maintained in separate enclosures, fed the sam diets, and as nearly as possible kept under the same conditions as regard crowding, water supply, and accessibility to infection with furunculosis an ulcer disease. The fish were exposed to both diseases simultaneously. Ever effort was made to spread the infections and to present the same chance o contagion to all lots. Bacteriological cultures were isolated at frequent intervals to verify the presence of the diseases. Moribund fish, fin-clipped fo identification, were spread around in all the lots. Fish which died from th diseases were ground up and fed to all the lots.

In Table 1 and 2 are presented the percentage mortalities to August 1 1953. Not all the mortalities were from furunculosis and ulcer disease, a at one period shortly after the arrival of the fish, bacterial gill disease exacted quite a toll. This was the chief cause of the high loss during the month of September in lot G (Table 1). Treatments for this disease were purposely withheld. By far the greater part of the losses, however, was caused by furunculosis and ulcer disease. Although both infections were present at all times, none of the brown trout ever exhibited symptoms of ulcer disease, and the causative organisms of this disease were recovered only from the brook trout.

The data show that water temperatures were the controlling factor in losses from disease in all lots. They also indicate that considerable variation exists in resistance to ulcer disease and furunculosis among strains of trout, especially brook trout. This variation affords material for genetic selection.

This review of some of the results which have been achieved in breeding animals for resistance to disease indicates that the method offers great possibilities, but truly useful results cannot be expected in a short time. Convincing evidence exists that genetic resistance to bacterial infection in trout can be increased through controlled breeding, and it is hoped that the present project can be continued for a sufficient number of years to establish a high degree of resistance to two of the most troublesome bacterial diseases. It should then be possible to eliminate the present use of chemotherapeutic methods of control which are costly and not always successful.

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Shad in the Hudson

y G. B. Talbot, *Chief, Middle Atlantic Fishery Investigations, Fish and Wildlife Service*

EVERY year around the last week in March an old industry begins anew in one of the biggest and busiest harbors of the world. This e Hudson River shad fishery. Each ng. beginning in the lower Hudson nst a back-drop of New York City s crapers and continuing upriver to vicinity of the City of Hudson. shad ermen undertake to harvest this de- able fish in the same manner they followed for some 300 years.

had are the largest members of the *peidae* or herring family in the United es and must ascend streams into fresh er to spawn. They congregate near mouths of rivers each year to make spawning run. The time of run de- ds upon the latitude; i.e.. the prevail- temperatures. In the St. Johns River Florida. for instance. the migration ins as early as November and reaches peak in December or January. Far- north in the Carolinas the run ches its peak in February or March. le in the Hudson River the bulk of fish arrives in April. The range of fish extends as far north as the St. wrence River in Canada, where the occurs in June.

n the Hudson River during March en water temperatures are still a frigid F., fishermen near the mouth of the er drive long lines of hickory poles the river bottom. Modern mechani- on has not influenced this fishery and poles are still driven by lashing on cross bar upon which the fishermen p in unison. forcing the poles into the er bottom. The poles are spaced about feet apart and support gill nets up to 0 feet long. In recent years the U. S. ny Engineers have designated separate as for fishing and for navigational pur- es so that both can be carried out ultaneously with a minimum of flict.

ill nets with a stretched-mesh size around 5½ inches are hung on the er or downstream sides of the poles before the flood tide begins. The s are removed at high slack tide. the removed. packed in boxes and iced shipment to market. Bucks (males) roes (females) are packed sepa- ely since the roes contain the eggs bring a much higher price. The ch by sex is nearly equal but since roes average a pound or two more n the bucks the total poundage of s landed is considerably higher.

hose shad which escape the nets in w York harbor continue up the Hud- into Haverstraw Bay. Here stake s are set in the shallow areas of the Bay. but since the river velocity is not as fast as in the lower river the nets are fished on both the flood and ebb tides. Because of the greater width of the river. however, these nets occupy a smaller proportion of the stream than the stake nets below and catch fewer fish per net.

Above Haverstraw Bay and extending to the City of Hudson, shad fishing is done almost entirely by drift gill nets. These are placed in the river during flood or ebb tides from skiffs usually carrying two men, and are set so that the net will not encounter snags or other obstructions during the drift—which may be for a period up to two hours.

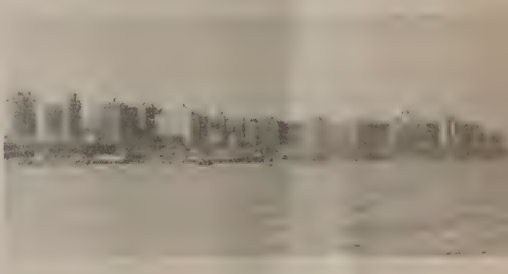
The nets are usually removed from the water at slack tide and hauled into the skiffs. If the water is clear. fishing is carried out at night. but if turbid conditions occur. fishing is done also during the day. Many of the fish caught upriver are purchased locally by nearby residents who eagerly look forward to obtaining the first shad of the season. Shad buyers purchase the balance and haul them to market by truck.

Some fishing is still done with haul seines. This method is gradually losing favor with the fishermen since a large crew is necessary and the profit per fisherman proportionately less. However, several of these still operate where sandy beaches allow the net to be hauled ashore and the catch removed. Often, many of the local residents will help with the haul to obtain fresh fish.

During the month of May when the water warms to above 50° F. shad begin to spawn. This activity takes place in the river principally between the cities of Hudson and Kingston. The eggs are broadcast loosely in the water by the roe shad and are fertilized by a buck swimming near her. After absorbing water the eggs are about ⅛ of an inch in diameter and are slightly heavier than water. They gradually settle to the river bottom where they are carried back and forth with the tide which affects the Hudson River as far up as the dam at Troy. The eggs hatch in 5 or 6 days and the young shad spend their first summer in the river. In the fall during October and November when the water begins to cool. the young shad move down the river to the sea. where they remain for the 4 to 5 years required to attain maturity.

During their stay in fresh water. adult shad eat practically nothing and by the time they have spawned they become emaciated. When caught by the fishermen these fish are called "downrunners." "racers" or "slabs." When they become

Biologists, using a drift net, tag and release shad near river mouth to continue up-river spawning run.



Stake gill nets set in Hudson off Manhattan produce large catches when shad run is good.

Hudson River shad fishermen engaged in hauling a seine near Village of Athens.

numerous in the catch fishing usually ceases for "racers" have little value. Those shad which aren't caught drift and feebly swim back to the ocean where they regain their strength and. if all goes well. they return again to the river the following spring.

Among the fishermen each year the big question is: "How will the shad run this year?" This is a good question. for the catch has fluctuated widely during the last 39 years during which good statistics have been kept. Even before 1915 there are records of "good" and "bad" years. For instance. Hudson River catches exceeding 4 million pounds between 1885 and 1890 are recorded. Then, in spite of the help of a shad hatchery with a production of 4 million to 17 million shad fry each year, the run began to drop off. By 1916 only 40.000 pounds were caught. The catch increased somewhat in the years following but remained fairly low until 1936 when the catch increased tremendously, and for the next ten years annual catches of around 3 million pounds were made. These large catches came at an opportune time, for during the World War II meat shortages, fish brought a good price and fishermen benefited accordingly.

After 1946, however, the runs of shad decreased again, and because the shad runs along the entire Atlantic Coast had also diminished, the Atlantic States Marine Fisheries Commission sponsored a coastwise study of this fish to determine methods of increasing and stabilizing the catch. This research project was begun in 1950 on the Hudson River by the U. S. Fish and Wildlife Service in co-operation with the New Jersey and New York Departments of Conservation.

A report on this research project has recently been completed, and is briefly reviewed here.

The total number of shad entering the river in 1950 was estimated by catching, tagging and releasing a percentage of them at the mouth of the river. A portion of these tagged fish were later captured by the fishermen along with those not tagged. Therefore, a ratio of untagged to tagged shad was obtained. The tag ratio was mutliplied by the number of tags affixed, which gave the estimate of total run.

The efficiency of each type of fishing gear was determined from an analysis of the catch by each. The total of all kinds of gear used was converted into "standard fishing units." Since data were available on catch and amounts and kinds of gear used each year for the past 39 years, it was possible to calculate the total standard fishing units for each of these years and to estimate the total size of run for each of these years by proper statistical procedures. An estimate of the spawning population or "escapement" for each year was then determined by subtracting the catch of each year from the estimated size of run for each year. The total size of run is much superior to the catch records for determining changes in the amount of shad present each year, since catches which depend upon the number of fishermen as well as the number of shad present, are sometimes misleading.

A sample of scales from a percentage of the shad caught by commercial fishermen was obtained throughout the season. From these, the age and number of times the fish have spawned can be read with the aid of a microscope. It was found that the greatest percentage of shad returned to the river and were caught at 4 and 5 years of age and that about 50 per cent of those caught had spawned previously and were returning to the river as "repeaters." With this information it was possible to study factors suspected of being responsible for the fluctuations in abundance of Hudson River shad.

A study of the dredging records of the U. S. Army Engineers was made to determine if dredging has been detrimental to the shad runs. This showed that the greatest removal of material had occurred in the Hudson River between 1928 and 1932 when the river was deepened to allow ocean-going freighters to navigate as far as Albany. After dredging, the numbers of large ships using the river increased greatly. No correlations were found, however, between dredging or ship traffic and the size of subsequent shad runs.

Water temperatures and river discharges were also studied but no relationships to subsequent shad runs were discovered.

From an analysis of the shad hatchery records and information concerning the fecundity of shad, it was discovered that shad hatcheries as operated in the past had no influence on shad production, or if any, it was deleterious rather than helpful.

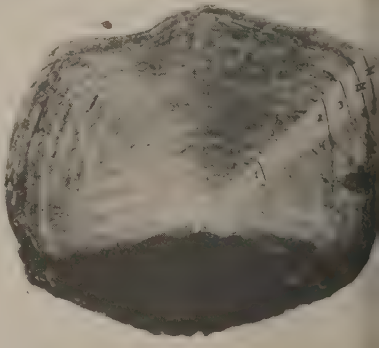
In 1951, with the help of the New York Health Department a water quality study was undertaken of the river between Troy dam and the mouth of the river. This entire section of the river was found to be seriously polluted, particularly below Albany and Troy, Poughkeepsie and New York City, all of which dump untreated sewage into the Hudson. Work has already begun on cleaning up the river below Bear Mountain Bridge by the Interstate Sanitation Commission, and the job is expected to be completed by 1959. Coincidentally the New York State Water Pollution Control Board has completed an intensive pollution study of the Hudson River. Their findings, which will be published in the near future, will be the basis for public hearings, scheduled this year, to determine the establishment of water purity standards upon which a progressive program for the abatement of pollution in the Hudson River will be undertaken.

In all probability productivity and certainly quality of fish would improve if pollution was cleaned up. This, incidentally, would greatly enhance the recreational value of this stream, for all of the many beautiful swimming beaches have by necessity been closed for several years because of the menace to health by pollution.

Since estimates of the spawning populations were calculated for each year it was possible to determine if there was any relation between these and subsequent size of shad runs. It was known from the age readings of the scales that the progeny of the fish spawning 4 a 5 years previous to any run make up bulk of the catch, and also that adults escaping the fishery the year fore made up a large portion of the f caught each year. Therefore, a compa son between the size of run each ye with the spawning population 5, 4 and year previous was made by a statisti process called a multiple regressi analysis. This showed that 85 per ce of the fluctuations in abundance of sh are associated with changes in the s of spawning populations. The questi has been raised as to whether this is casual relationship, and if so, which cause and which is effect. All availab evidence, however, seems to point to t fact that the population size depen upon the spawning populations. Furth work in progress should clarify this poi

The conclusion reached in this stud assuming that size of spawning popul tion does control population size, is th this fishery can be stabilized at a hig productive level by allowing the optimu number of shad to escape the fishery ea year to spawn. This can be achieved regulating the commercial fishery closing the waters to fishing for appr priate periods each week. This shou work no hardship on the fishermen, f this is truly a case of being able to e your cake and have it too—those sha which are not caught, but allowed spawn, produce fish which return to th river predominantly 4 and 5 years late and they themselves return to the rive the following year as bigger and bette fish ready to be captured.

With the aid of scientific research proper regulation and conservation mea ures, it would appear that this old an picturesque fishery can continue to com pete with modern civilization and wi continue to produce for countless year to come.



Scale from 6-year-old shad shows method of determining age. Arabics indicate marks made during winter in sea. Roman numerals show spawning marks formed during two migrations.

Reprinted from:

THE NEW YORK STATE
Conservationist

APRIL-MAY, 1954

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1954, v1, 149-155

Trichodina myicola n. sp., a Peritrichous Ciliate from the Marine Bivalve *Mya arenaria* L.

J. R. UZMANN AND A. P. STICKNEY*
U. S. Department of the Interior, Fish and Wildlife Service, Clam Investigations, Milford, Connecticut, and Newburyport, Massachusetts

SUMMARY. A new ciliate from the marine clam *Mya arenaria* is described and figured. The form is designated *Trichodina myicola* with specific characters as follows: Bell-shaped to discoidal; length 31-86 microns; diam. 62-103 microns; diam. denticulate ring 29-46 microns; 26-36 denticles; diam. of basal disk 42-79 microns; adoral ciliary spiral performs slightly more than one turn; posterior ciliature in three closely applied, concentric tiers: an anterior circlet of marginal cilia, a middle circlet of overlapping membranelles, and a posterior circlet of inner cilia; macronucleus C-shaped; micronucleus small, round, lying near outer curvature of left arm of macronucleus; large contractile vacuole present near end of left arm of macronucleus.

Taxonomy in the genus *Trichodina* is discussed and outlined. Special attention is given to details of the oral ciliature. *T. myicola* is compared with other members of the genus. A checklist of *Trichodina* species is presented.

THE FIRST RECORD of a trichodinid from a marine lamellibranch is that of Delphy(7), who described *Cyclochaeta cardii* from the pallial cavity of *Cardium edule* from the region of Arcachon on the Bay of Biscay. The present species, *Trichodina myicola* is the second to be reported and was first encountered by one of us (J.R.U.) in January 1952 in specimens of the soft-shell clam, *Mya arenaria*, from Sagadahoc Bay, Sagadahoc County, Maine. A short time later this form was independently discovered by the second author in *M. arenaria* from Plum Island Sound, Essex County, Massachusetts. The ensuing account is the result of collaborative study with the writers sharing equal responsibility.

T. myicola is an epizoic commensal which strongly attaches to epithelial surfaces in the oral region of its host. The greatest concentrations of these peritrichs are found on the outer faces of the palps where numbers may run as high as 100 or more to each of the four palps. Occasional specimens are found on the wall of the visceral body and on the internal face of the pallial muscle. Frequency of infection with *T. myicola* in samples of *Mya* from endemic areas ranges from 0 to 62% with highest percentages and degrees of infection occurring in late spring. *T. myicola* is often accompanied by the parasitic thigmotrich *Ancistrocoma myae*. Several specimens of *T. myicola* were found to be parasitized by a suctorian, *Endosphaera* sp., possibly *E. engelmanni* as reported by Padnos and Nigrelli(23,24) from other *Trichodina*.

Microscopical study of the living ciliates was sufficient to define much of the general morphology of this species. For revelation of nuclear detail, specimens were fixed in Schaudinn's fluid and stained with iron hematoxylin; excellent results were also obtained with the Feulgen method following acetic-sublimate fixation. Studies on host-parasite relationships and details of the basal disk were made from paraffin sections of ciliates fixed *in situ* with Zenker-acetic or Bouin's fluid and stained with Harris hematoxylin. Precise definition of ciliary patterns was obtained using a modification of the silver impregnation method of Chatton and Lwoff as outlined by Corliss(3).

The genus *Trichodina* comprises a highly adaptive and specialized group of epizoic peritrichous ciliates which are parasitic or commensal upon a wide variety of fauna. At the present time, some 50 species referable to *Trichodina* have been reported from 10 classes of fresh water and marine hosts (Table I).

The parasitic habit is highly developed in vertebrate associations, but grades toward commensalism with invertebrates. The majority of reported species are ectoparasitic upon the gills and body surfaces of various species of fishes where they feed upon desquamated epithelial cells and erythrocytes. Irritation from heavy infections may lead to hyperplasia, extravasation, secondary infection, and possibly, to the death of the fish host(6,21,23).

Endoparasitic forms have been reported from fishes (5,19,20), amphibians(1,4,9,10,13,16) and from a land gastropod(9).

As may be seen in Table I, a considerable number of trichodinids are known from invertebrates. There is little evidence that any of these are significant parasites, if parasitic at all. Most of them are probably little more than annoying commensals which benefit from the food gathering propensities of their hosts. Hirshfield(15) reported that the food vacuoles of *Trichodina tegula* from the marine gastropod *Tegula funebralis* contain bacteria. Richards(25) reported zoochlorellae in *T. chlorophora* from certain fresh water gastropods.

The general morphology of trichodinids has been reviewed in the excellent and comparatively recent studies of Fauré-Fremiet(10), Fauré-Fremiet and Thaureux(12), and Davis(6). These authors have

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* Present address: U. S. Fish & Wildlife Service, Boothbay Harbor, Maine.

TABLE I. Zoological distribution of *Trichodina*.*

Species	Host
Pisces	
Fresh water:	
T. baltica Quennerstedt, 1869	*Neritina fluviatilis*
T. domergue (Wallengren, 1897)	*Gasterosteus, Carassius, Perca, Esox, Phoxinus*
T. renicola Mueller, 1931	*Esox niger*
T. truttae Mueller, 1937	*Salmo clarkii*
T. myakkae Mueller, 1937	*Micropterus, Ictiobus, Carpiodes, Salvelinus*
T. nephritica (Mueller, 1938)	*Esox masquinongy*
T. guberleti (MacLennan, 1939)	*Richardsonius, Apocope*
T. bulbosa Davis, 1947	*Margariscus margarita*
T. discoidea Davis, 1947	*Lepomis, Pomoxis, Ambloplites, Ictalurus*
T. bursiformis Davis, 1947	*Ambloplites rupestris*
T. californica Davis, 1947	*Oncorhyncus tshawytscha*
T. fultoni Davis, 1947	*Micropterus, Lepomis, Ambloplites, Salmo*
T. platyformis Davis, 1947	*Margariscus, Rhinichthys*
T. symmetrica Davis, 1947	*Ictalurus, Margariscus, Rhinichthys*
T. tumefaciens Davis, 1947	*Cottus bairdii*
T. vallata Davis, 1947	*Ictalurus lacustris*
T. tenuidens Fauré-Fremiet, 1943	*Gasterosteus aculeatus*
Marine:	
T. scorpaenae (Robin, 1879)	*Scorpaena, Trigla*
T. bidentata Fabre-Domergue, 1888	*Scorpaena*
T. scorpaenicola (Fabre-Domergue, 1888) nom. nov. [= *T. scorpaenae* (F-D)]	*Scorpaena*
T. labrorum Chatton, 1910	*Symphodus* spp.
T. fariai DaCunha & Pinto, 1928	*Spheroides testudineus*
T. blennii Fantham, 1930	*Blennius cornutus*
T. chelidonichthyos Fantham, 1930	*Chelidonichthys capensis*
T. clini Fantham, 1930	*Clinus* spp.
T. mugilis Fantham, 1930	*Mugil capito*
T. halli Padnos & Nigrelli, 1942	*Spheroides maculatus*
T. spheroidesi Padnos & Nigrelli, 1942	*Spheroides maculatus*
T. branchicola Tripathi, 1948	*Ciliata, Gaidopsaurus, Cottus, Spinachia, Blennius, Trigla, Pleuronectes*
Amphibia	
T. pediculus Ehrenberg, 1838	*Necturus, Triturus, Bufo*
T. domerguei (Wallengren, 1897)	*Triton*
T. urinicola Fulton, 1923	*Necturus, Bufo*
T. bufonis Fantham, 1924	*Bufo regularis*
T. xenopodos Fantham, 1924	*Xenopus laevis*
T. okajimae Ibara, 1931	*Hynobius tokyoensis*
T. entzii Breitschneider, 1935	*Rana esculenta*
T. vesicularum Fauré-Fremiet, 1943	*Triton, Rana*
T. ranae DaCunha, 1950	*Rana ridibunda*
Gastropoda	
Fresh water:	
T. breviradiosa Richards, 1949	—
T. chlorophora Richards, 1949	—
T. helisomarum Richards, 1949	*Helisoma*
T. physellarum Richards, 1949	*Physella*
Marine:	
T. tegula Hirshfield, 1949	*Tegula* spp.
Terrestrial:	
T. achatinae Fantham, 1924	*Achatina zebra*
Pelecypoda	
Fresh water:	
T. domerguei (Wallengren, 1897)	*Unio*
Marine:	
T. cardii (Delphy, 1938) n. comb.	*Cardium edule*
T. myicola n. sp.	*Mya arenaria*
Echinoidea	
Trichodina sp. (Powers, 1933)	*Strongylocentrotus droehbachiensis*
Asteroidea	
T. asterisci (Gruber, 1884)	*Asteriscus*
T. ophiotricis (Fabre-Domergue, 1888)	*Ophiotrix fragilis*
T. astericola (Precht, 1935)	*Asterias rubens*
T. astropectinis (Chatton & Villeneuve, 1937) n. comb.	*Astropecten bispinosus*
Gephyrea	
Trichodina sp. (Embleton, 1901)	*Echiurus unicinctus*
Turbellaria	
T. steinii Claparede & Lachmann, 1858	*Polycelis, Dugesia*
Hydrozoa	
T. pediculus Ehrenberg, 1838	*Hydra* spp.
Demospongia	
T. spongillae (Jackson, 1875)	*Spongilla fluviatilis*

* *Trichodina* Ehrenberg, 1830. Syn. *Cyclochaeta* Jackson, 1875; *Cyclocyrrha* Fabre-Domergue, 1888; *Anhymenia*, Fabre-Domergue, 1888; *Vauchomia* Mueller, 1938.

emphasized and demonstrated the taxonomic importance of the skeletal ring in the problem of specific determination. The reproductive process of conjugation has been described for a marine species, *T. spheroidesi*, by Padnos and Nigrelli(23), and by Davis (6), for trichodinids in general, on information from eight species. Davis has shown that both isogamous and anisogamous conjugation may occur in *Trichodina* and that the size disparity between conjugants is only a matter of age. The multiplicative process of binary fission has been aptly described by several authors in essential accord with each other(6,8,12,13, 23). Division of the mouth and peristome at fission has been carefully studied and figured by Chatton and Villeneuve(2).

Fauré-Fremiet(10) presented a systematic review of the family Urceolariidae and provided a workable taxonomic scheme which adequately embraces the most salient features of the assigned members. The genus *auchomia* Mueller, 1938 was not treated, however, ut will be considered in the latter part of this discusion. Considering six genera assigned to the family rior to the proposal of *Vauchomia*, Fauré-Fremiet etained only two with full rank, *Urceolaria* Stein, 867 and *Trichodina* Ehrenberg, 1830. *Leiotrocha* abre-Domergue, 1888 was regarded a sub-genus of *rceolaria*, and *Cyclochaeta* Jackson, 1875, a subenus of *Trichodina*; *Leiotrocha* and *Cyclochaeta* iffer from the sub-genera *Urceolaria* and *Trichodina*, respectively, in having a circlet of cirri supplemental to the ciliary girdle. The genera *Cyclocyrrha* Fabre-Domergue, 1888 and *Acyclochaeta* Zick, 1928 were suppressed. Thus, forms referable to the genus *Urceolaria* are distinguished from *Trichodina* by the absence of hooks and rays on the elements of the skeletal ring, other features notwithstanding.

Tripathi(26) concurred with Fauré-Fremiet(10) and further considered *Vauchomia* a synonym of *Trichodina*. He presented a useful summary of data on many species of *Trichodina* and redesignated several forms previously referred to *Cyclochaeta* and *Vauchomia*. Hirshfield(15) adopted and delineated the scheme of Fauré-Fremiet and agreed with Tripathi in placing *Vauchomia* in strict synonomy with *Trichodina*. Hirshfield also provided a checklist of forms referable to *Urceolaria* including therein two forms previously referred to *Trichodina*.

We are in agreement with the rationale of Fauré-Fremiet(10) but cannot reject *Vauchomia* as readily as others have done. The differences which characterize *Vauchomia* appear to be no less significant phylogenetically than those which characterize the subgenera *Trichodina* and *Cyclochaeta*.

Mueller(20) proposed *Vauchomia* to contain those endoparasitic urceolariids ". . . having an adoral spiral of cilia which performs two to three complete turns of the body . . ." and in which ". . . the striated ring is compound, consisting of a posterior ring of hyaline rays and an anterior ring of soft rays (myonemes) . . .". Since the latter feature has since been demonstrated in carefully studied ectozoic *Trichodina* as well, it loses taxonomic significance. The former feature warrants further consideration, however, in view of the established importance of variations in stomatogenesis and peristomial development in other ciliates. The multiple adoral ciliary spiral of *Vauchomia* is in marked contrast to other trichodinids which display an adoral spiral of only one turn more or less. Excepting this notable difference, however, *Vauchomia* agrees with *Trichodina* (*Trichodina*) in all other essential respects. We have, accordingly, adopted a conservative view toward *Vauchomia* and propose that it be accepted as a third sub-genus of *Trichodina*. Thus, the genus *Trichodina* and its sub-genera may be defined in the following manner:

Genus *Trichodina*: Urceolariidae with skeletal ring of basal disk composed of a variable number of interposed cone-like elements (denticles) having medially projecting rays and distally projecting blades.

A. Adoral ciliary spiral performs less than two turns.
   1. Ciliary girdle with supplementary circlet of cirri . . . . sub-genus *Cyclochaeta*
   2. Ciliary girdle without circlet of cirri . . . . . . sub-genus *Trichodina*

AA. Adoral spiral performs more than two turns.
   1. Ciliary girdle as in *T.* (*Trichodina*) . . . . . . sub-genus *Vauchomia*

Following the scheme outlined above, the presently proposed species is fully designated *Trichodina* (*Trichodina*) *myicola* and needs be distinguished only from other members of the sub-genus to which it is assigned.

For purposes of orientation, the side of *Trichodina* bearing the mouth is here considered ventral. Arbitrarily, the convex end is considered anterior and the basal end posterior. We prefer this orientation for the comparison of trichodinids because the use of the "oral-aboral" axis of orientation is illsuited to this group. It should be noted that axial homologies between the peritrichs and other ciliates are uncertain (11,14).

Marine peritrichous ciliate. Bell-shaped to discoidal in form depending upon the degree of expansion or contraction. Circular in outline in anterior and posterior aspect with a diameter of 62-103 (Av. 81) microns. Length or "height" variable from 31-86 microns. Cytostome ventral and slightly anterior to mid-body level. The cytostome and cytopharynx lie at the terminal end of a moderately deep and inclined vestibulum which has its outer wall expanded in the form of a lip. The cytopharynx is in the form of a slender vortex which plunges sharply inward from the deep end of the vestibulum to terminate in the right ventral quadrant of the cell.

As viewed from the anterior pole, the adoral ciliary spiral is a complex of two parallel rows of closely set cilia fused for some distance above their bases to form a pair of closely applied semi-membranes. They arise in the right ventral quadrant of the cell just anterior to the level of the mouth. These paired rows spiral adorally counter-clockwise in slight excess of 360° and then diverge (Fig. 3) and enter the immediate region of the cytostome along the outer wall of the vestibulum. The row which was formerly the outer ciliary spiral (haplocinétie of Chatton) follows the outer rim of the vestibulum and crosses the median axis of the cytopharynx; from this point, it completes its circuit about the vestibular lip and plunges sharply inward,

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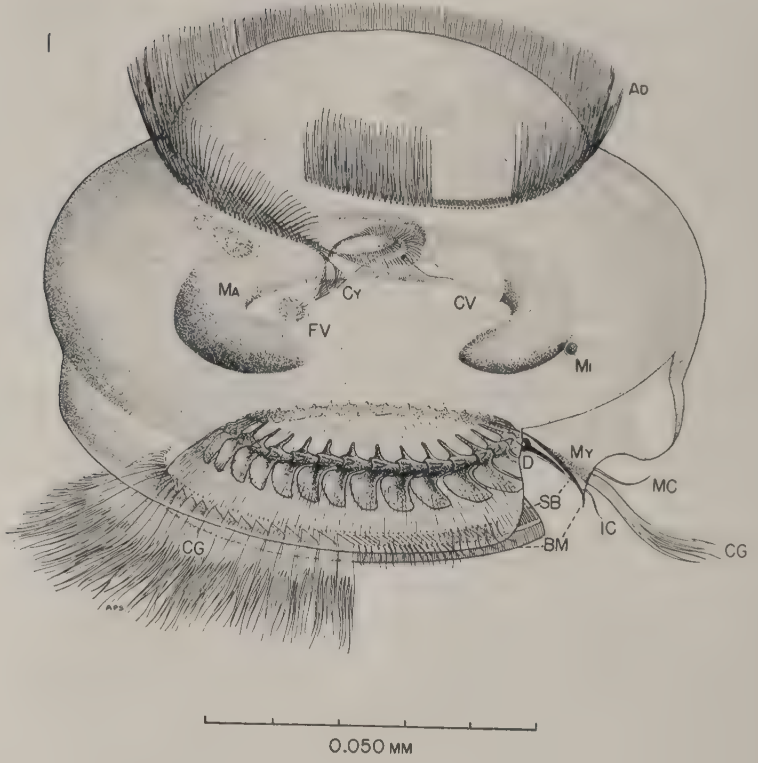
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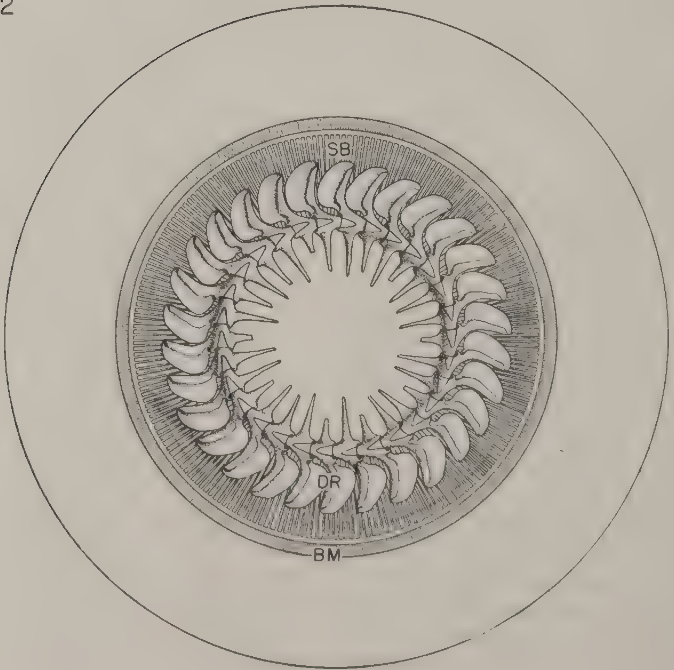


in the meanwhile performing a 180° circuit to define the upper left margin of the cytopharynx. This spiral is continued through a second 180° circuit to define the right margin of the cytopharynx where the cilia appear to terminate or become shortened beyond resolution (Fig. 5, H-360).

The inner ciliary row (polycinétie of Chatton), having diverged from the outer row at the vestibular entrance, descends more steeply on the wall of the vestibulum and passes the median axis of the cytopharynx at a much deeper level within the vestibule (Fig. 3). Within the vestibulum and cytopharynx it follows the margin of a fairly broad argentophilic plaque, the significance of which is uncertain. At the point of crossing the cytopharyngeal axis it has attained maximal divergence from its counterpart and its spiral course, although still counter-clockwise, has shifted 180° out of phase with that of the outer ciliary row; from this point of reference, the cilia spiral into the cytopharynx traversing the left wall through 180° (Fig. 5, P-180) and thence over the right wall through another 180° to terminate on the ventral wall well beyond the termination of its opposing spiral (Fig. 5, P-360).

Issel(17) and Fauré-Fremiet & Thaureux(12) have found in related forms a skeletal structure closely associated with and underlying the ciliary rows throughout their length; the structure is shown to be continuous in its course underlying the adoral spiral but separated into two terminally fused elements in the pharyngeal region.

The cilia of the outer ciliary spiral appear to be fused for the greater part of their length where they border the outer lip of the vestibulum. Silver preparations show further complication of this lip in a series of extremely fine, short radii emanating from the basal region of the cilia. It is possible that these features are homologous with the undulating membrane complex of certain spirotrichs and holotrichs(11).

The posterior ciliature consists of three closely applied but distinct concentric tiers located just anterior to the border of the basal disk. The anterior circlet or *marginal cilia* (Fig. 1, MC) are short, fine, loosely spaced cilia 7-9 microns in length; these cilia are probably homologues of the cirri characteristic of the subgenus *Cyclochaeta*. The middle circlet or *ciliary girdle* (Fig. 1, CG) is a series of overlapping membranelles 23-25 microns in length inserted in a shallow groove in the pellicle. The membranelles are frayed into component cilia distally; these membranelles serve as the principal locomotor organelle. The posterior circlet or *inner cilia* (Fig. 1, IC) are closely set, short, fine cilia 5-6 microns in length inserted immediately anterior to the border of the basal disk. The significance of this inner row is uncertain.

T. myicola does not exhibit a velum. It seems pertinent to note here that the term "velum" as applied to trichodinids refers specifically to a well-developed undulating skirt-like expansion of the pellicle immediately overlying the posterior ciliature. The term was proposed by James-Clark(18) for a specific feature of *T. pediculus*. In *T. myicola* and in most other trichodinids, a comparable organelle is lacking. In spite of the absence of this feature, some authors have applied the term to the equivalent general region of subsequent species. The original meaning of the term has been further confused by its use for entirely different organelles(13,15,22,27).

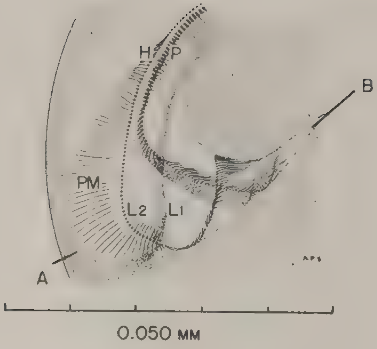
The adhesive or basal disk is concave, circular in outline and varies from 42-79 (Av. 62) microns in diameter. The disk is reinforced by a band of radially arranged ribs or striae which are attached to a narrow pellicular band about the periphery (Fig. 2, SB). The free ends are finely tapered and terminate half-way into the center of the disk. A system of radiating myonemes is present in conjunction with the striae; these myonemes extend from the mid-point of the anterior side of the striae to the bases of the membranelles of the ciliary girdle (Fig. 1, MY). There are five to nine striae to each element of the skeletal ring, the number varying directly with the size of the disk. Each of the striae has an argentophilic swelling slightly inward from its point of attachment.

The skeletal or denticulate ring is 44-62 (Av. 53) microns in outside diameter, 29-46 (Av. 36) microns in ring diameter, and lies immediately posterior to the striae of the disk. The ring is composed of a series of articulated elements or denticles ranging in number from 26-36 with a mode at 29. (Fig. 2, DR). Each denticle consists of a conical centrum, a proximal spine or ray and a distal hook or blade. The blades are convex and very thin on one edge and slightly concave

Fig. 1. *T. myicola*, ventral aspect. Semi-diagrammatic reconstruction of entire organism from living and stained material, silver preparations, and sections. Cutaway shows detail of basal disk and associated ciliature in section. Posterior ciliary rows are not shown in their entirety for the sake of clarity. The ciliary girdle is depicted with every third membranelle attached; the membranelles are discontinued at the right of center in order to indicate more clearly the relative disposition of the three ciliary systems. The marginal cilia and inner cilia are shown only in a limited sector of their circumference. Fig. 2. *T. myicola*, posterior aspect. Semi-diagrammatic representation of basal disk showing details of denticulate ring, striated band, and border membrane.

Ad, Adoral cilia. BM, Border membrane. CG, Ciliary girdle. CV, Contractile vacuole. Cy, Cytopharynx. D, Denticle. DR, Denticulate ring. FV, Food vacuole. IC, Inner cilia. Ma. Macronucleus. Mi, Micronucleus. MC, Marginal cilia. My, Myoneme. SB, Striated band.

3



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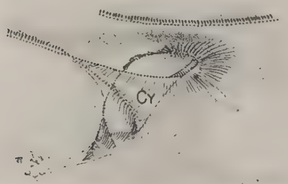

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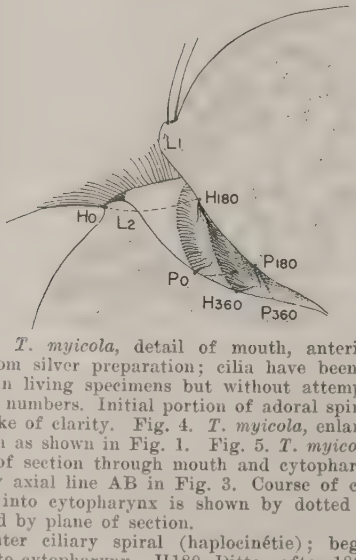

Fig. 3. *T. myicola,* detail of mouth, anterior aspect. Drawn from silver preparation; cilia have been added as observed in living specimens but without attempt to indicate exact numbers. Initial portion of adoral spiral omitted for the sake of clarity. Fig. 4. *T. myicola,* enlargement of oral region as shown in Fig. 1. Fig. 5. *T. myicola.* Reconstruction of section through mouth and cytopharynx as indicated by axial line AB in Fig. 3. Course of ciliature as it spirals into cytopharynx is shown by dotted line when interrupted by plane of section.

HO, Outer ciliary spiral (haplocinétie); beginning of descent into cytopharynx. H180, Ditto; after 180° descent. H360, Ditto, after 360° descent. PO, Inner ciliary spiral (polycinétie); beginning of descent into cytopharynx. P180, Ditto; after 180° descent. P360, Ditto; after 360° descent. L1, Inner lip of vestibulum. L2, Outer lip of vestibulum. PM, Paroral membrane.

on the other; the concave edge is relatively thicker and is further strengthened by a posterior incurved flange.

The nuclear elements are typical of the genus. The macronucleus is large, C-shaped, and lies in a plane parallel to the equatorial plane of the cell. It is so oriented that its open ends are on the side of the body bearing the mouth and contractile vacuole. A small micronucleus lies close to the outer curvature of the left arm of the macronucleus. A large contractile vacuole is located just anterior to the left arm of the macronucleus and discharges to the exterior of the organism through a permanent ampulliform canal which opens just beneath the lip of the peristome. The contractile vacuole of peritrichs is ordinarily described as opening into the cytopharynx or vestibulum. This generalization does not hold true for some species of *Trichodina,* however. In addition to the present exception, Davis(6) stated that at least three of the species of *Trichodina* studied by him showed an aboral opening of the contractile vacuole. Food vacuoles are distributed about the body and show a tendency to collect in the anterior portion of the cell. Osmiophilic globules indicative of lipid reserves may be seen in occasional preparations following fixation with Champy's fluid.

From the foregoing information, *T. myicola* may be differentiated from previously reported species referable to *Trichodina.*

Trichodina myicola differs from the following members of the sub-genus *Cyclochaeta,* the members of which have a posterior circlet of cirri: (For authors and dates, see Table I)

T. spongillae, T. domerguei, T. asterisci, T. ophiotricis, T. astericola, T. astropectinis, T. guberleti, T. cardii, T. tegula, T. scorpaenae (Robin).

T. myicola differs from the following members of the sub-genus *Vauchomia,* the members of which have an adoral ciliary spiral exceeding two turns about the body:

T. renicola, T. nephritica.

T. myicola, like all members of the sub-genus *Trichodina,* lacks posterior cirri and has an adoral ciliary spiral of less than two turns; the following members of the sub-genus are differentiated from *T. myicola* on physiological grounds. Precise differentiation on morphological or biometrical bases is possible with only a limited number of these forms; in some instances, chief reliance must be placed on undetailed figures and general data; in a few instances, no figures are available and the data given are without specific value. In view of these conditions we have emphasized the taxonomic significance of physiological differences which are evident or implied in the host-*Trichodina* relationships. Additionally, however, consideration of such positive morphologic information as is available allows us to separate practically all of these forms from *T. myicola* (forms so distinguished are marked with an asterisk).

Ectoparasitic on fresh water fishes:

**T. truttae,* **T. myakkae,* **T. tenuidens,* **T. dis-*

*oidea, T. platyformis, *T. vallata, *T. fultoni, *T. ymmetrica, *T. californica, *T. tumefaciens, *T. bulosa, *T. bursiformis, *T. baltica.*

Endoparasitic in amphibians:

**T. urinicola, *T. ranae, *T. vesicularum, *T. entzii, T. xenopodos, *T. bufonis, *T. okajimae.*

Ectocommensal on fresh water invertebrates:

**T. steinii, *T. pediculus, T. chlorophora, T. breviadiosa, T. physellarum, T. helisomarum.*

Endoparasitic in land snail:

T. achatinae.

Ectoparasitic on marine fishes:

**T. bidentata, *T. labrorum, *T. chelidonichthyos, *T. mugilis, *T. blennii, *T. clini, *T. halli, *T. spheroidesi, *T. branchicola, *T. scorpaenae* (Fabre-Domergue).

Endoparasitic in marine fish:

**T. fariai.*

Endozoic in marine invertebrates:

**Trichodina* sp. (Powers) . . . intestine of sea urchin.

**Trichodina* sp. (Embleton) . . . intestine of echiurid worm.

A case of secondary homonymy is apparent in *T. scorpaenae* (Robin, 1879) and *T. scorpaenae* (Fabre-Domergue, 1888); although the former species is referable to the sub-genus *Cyclochaeta*, and the latter to the sub-genus *Trichodina*, the rules of zoological nomenclature are unsatisfied. We propose, therefore, to redesignate the later species as *T. scorpaenicola* (Fabre-Domergue, 1888) nom. nov.

In accord with the taxonomic scheme used in this paper, the species *Cyclochaeta astropectinis* Chatton and Villeneuve, and *Cyclochaeta cardii* Delphy are redesignated *Trichodina* (*C.*) *astropectinis* (Chatton and Villeneuve) n. comb. and *Trichodina* (*C.*) *cardii* (Delphy) n. comb.

We are indebted to our colleagues J. B. Glude and H. S. Spear of the U. S. Fish and Wildlife Service Laboratory, Boothbay Harbor, Maine for generous assistance in obtaining material from the type locality. Grateful acknowledgement is extended to Dr. John O. Corliss of Yale University for helpful advice and critical review of the manuscript.

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FLUCTUATING FISHERY STOCKS

Fluctuating Fishery Stocks: What We Know about This World-wide Riddle

L. A. Walford, Chief,
anch of Fishery Biology,
h and Wildlife Service

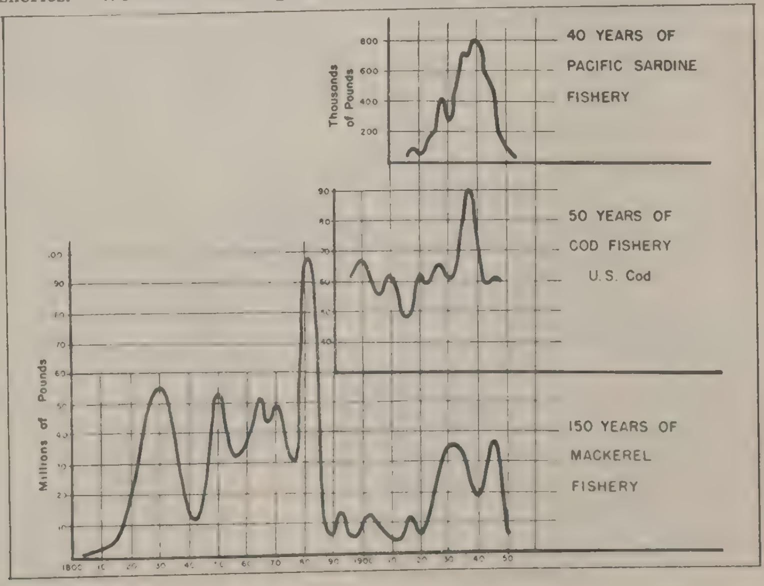
Part I—The Problem; Some Contributing Factors

Many of you are concerned about e condition of your fishery stocks, veral of which seem to have receded a low ebb of abundance in recent ars. You are asking what has hapned to pink salmon, to Alaska herng, to Maine sardines, to the Pacific rdine, to the Gulf of Mexico shrimp. re there fewer of them in the sea? have they perhaps retreated to stant, more obscure areas and beme less accessible to fishermen? hatever the nature of the condition ay be, is it permanent? It is not ly Americans who are concerned ith these questions. So are people other parts of the earth, for comarable conditions have occurred elsehere, not only in California, Maine nd Alaska, but also in such distant nd widely separated places as Japan, ndia, Spain, North Africa. Is this l the result of mere coincidence? ould any important part of this effect ave sprung from some common cause npelled by such a cosmic influence as eather, for example, which might ffect these diverse species in a simiar way? Are all these recent and urrent seemingly peculiar conditions ithin the range of normal variation? hat last question is most important, ecause the seriousness of present onditions can be judged only in comarison with some standard; and that standard, which we call the normal cannot be simply defined.

In the language of our everyday conversation, the word "normal" tends to have the rather fuzzy meaning of things-as-they-should-be. Lucky is the "perfectly normal man." There is nothing wrong with him. It will be a fine thing when "the country gets back to normal again," when our domestic and international problems have become resolved. When enough food is produced to feed the millions of hungry people of the world, they can enjoy "normal lives." Those are conceptions we hear on every side. In its popular connotation, normal is the good state of affairs, the good life. In the language of the statistician, it is something quite different—not nearly so cheerful a word, but very much more exact. It is simply the average, the sum of all the items divided by the number of items—the lean years and the fat, the good and the bad, the tall and the short—whatever it may be that we are talking about.

We are talking about fishes and invertebrate animals that happen to be commercially useful for canning. Exact information about the history of these species is limited to relatively few recent years when they have lived under the pressures of intense fisheries. We know nothing about their fortunes under virgin conditions. In those days, did they go through alternating periods of great abundance interspersed with periods of contrasting scarcity? What was their normal life then? We cannot tell. A great part of what we can learn now we must deduce from the catches of fishermen. Thus, in searching for normal patterns about the complex lives of fishes in order to understand the significance of events in a single year like the last, we must take into account patterns in the complex affairs of men. The behavior of fishermen fluctuates in response to economic conditions; and for that reason as well as others the intensity of fishing rarely remains constant long. Fishing techniques improve, fishing fleets increase in size, and markets change. And because recorded history about these aspects of fisheries is usually exasperatingly fragmentary, it is difficult to draw absolutely certain conclusions about normal conditions of fish or of fisheries. This much, however, seems clear: conditions have rarely been "normal," as I will show you in these few graphs:

Figure I. Fishery harvests are characteristically unstable, subject to irregular oscillations. This is illustrated in schematic representations of 150 years of Atlantic mackerel fishing, 50 years of American cod fishing, and 37 years of Pacific sardine fishing.



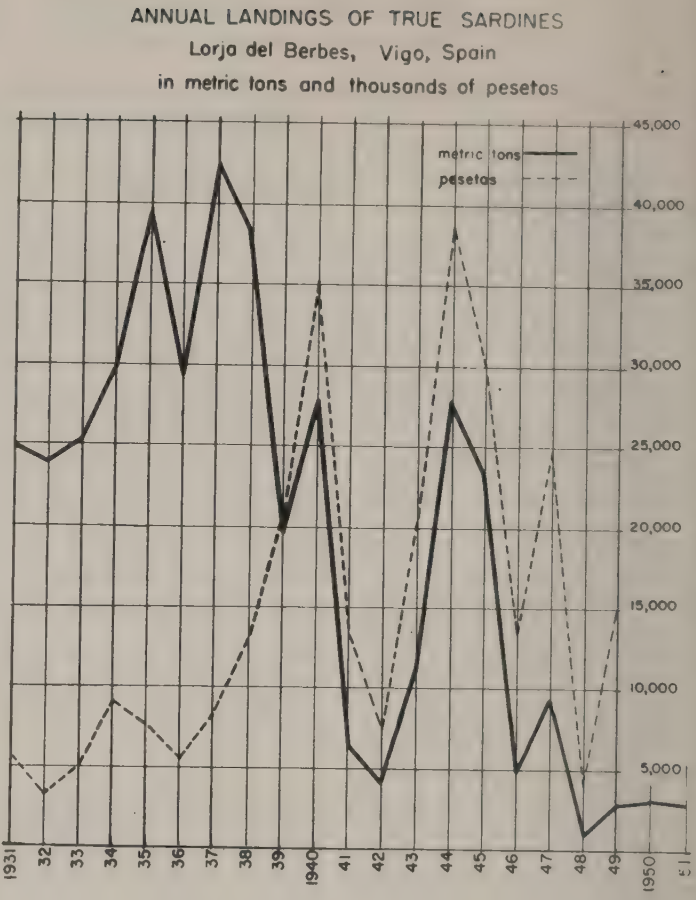


Figure II. A graphic record of 20 years of sardine fishing in northern Spain.

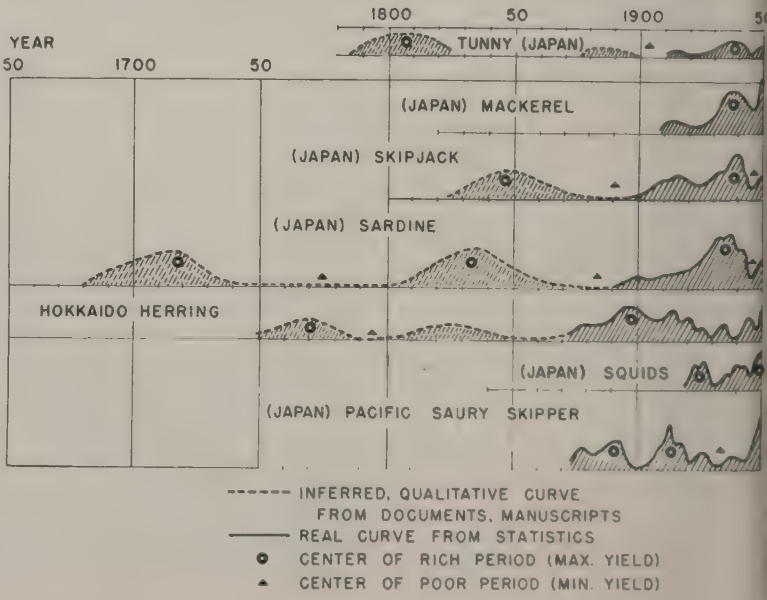


Figure III. In 300 years of Japanese fishing for tunny, skipjack, herring, squid, and saury, periods of abundance alternate with periods of scarcity. Data are not statistically good enough to demonstrate any periodicity in these waves; nevertheless some Japanese scientists interpret that waves of maximal abundance have occurred about as follows: tunny 60 years apart, skipjack 80 years apart, sardine 100 years apart, and Hokkaido herring 50 years apart.

Part of the fluctuations shown in these records reflects economic conditions, part reflects the degree of accessibility of the fish on fishing grounds, and part—surely a very important part—reflects fluctuating abundance of the fish. Fishery biologists work continually to resolve these influences and have made much progress in that effort. They have long been in general agreement that fluctuations in environmental conditions cause fluctuations in abundance of the fish; but what elements of the environment are critical and by what mechanisms they affect the survival of fish, are problems that remain largely unsolved. As long as that is true, fishing must continue to be the uncertain occupation that it is.

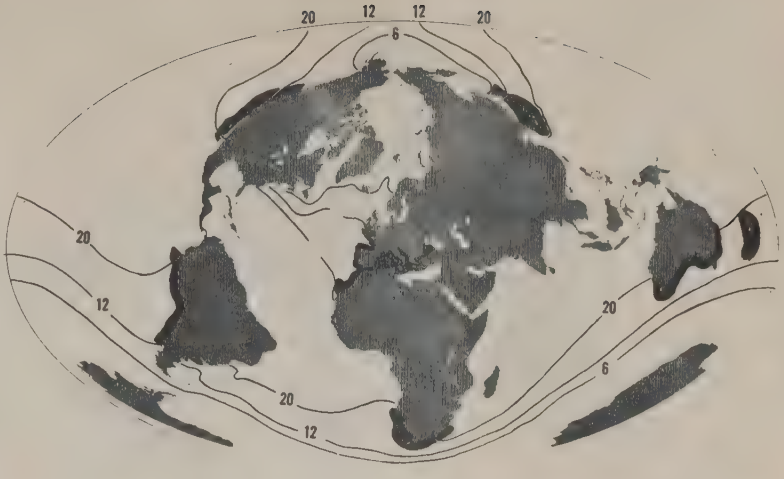
Agricultural science is far ahead of fishery science in understanding the biology of the environment and making use of that understanding. But then, of course, the problems of agriculture, difficult though they may be, are very much simpler than those of fisheries. For the farmer has the enormous advantage over the fishery man of being able to perceive his produce as it develops; and there are various things he can do to protect it when a period of unfavorable weather hits, such as a cold spell or drought. Because the farmer can follow the vicissitudes of his produce with his eyes, he is constantly aware of what is happening on his land. He knows the limits of his piece of the environment and he can put a fence around it which will contain his crops and his animals; and therein they will stay until he is ready to harvest them.

The fishery man enjoys none of these advantages. The environment in which he is most interested, the body of water in which dwell the fishery stocks that give him his living, is continually moving, changing direction, position, levels. Now it is close to the shore, now far at sea, now at the surface, now deep in the depths. It expands and contracts, like a living thing; and as far as we can tell, the fishery stocks which it contains tend always to fill it to its capacity and to remain in it wherever it goes. But its capacity evidently also changes constantly. All the evidence which has accumulated about the natural history of aquatic animals indicates that their environments have limits beyond which they cannot stray very far. How can we define those limits? How can we distinguish a body of water which contains all the materials that attract mackerel from a body of water which repels them?

One of the most obvious boundaries of the territory in which an aquatic animal can live is temperature. Fish are exceedingly sensitive to temperature. I will give you one example to illustrate this point.

Dr. H. O. Bull, a marine biologist working at the Dove Marine Laboratory, Cullercoats, England, became interested in learning just how sensitive a fish is to various qualities of the environment. What does a fish feel? That was the sort of question he asked, a very difficult question because fish feel and respond to many different stimuli. So it was necessary to build special aquaria designed to permit him to exclude all stimuli except the one being studied. So he carried on a number of experiments to test the sensitivity of cod fish to temperature. First he conditioned the fish to associate the presence of food with a change of temperature. Then, having done that, he determined what degree of change the fish would respond to by observing the minimal temperature at which it would perform a complex task in order to get food. He kept the fish in a specially constructed tank with the floor inclined so that one end was deep enough to provide a habitable living space and the other end extended out of the water. He introduced the food into a chamber at the upper end of the inclined floor. Gradually, over the many days that the conditioning process went on, the fish learned that food was in the chamber when the temperature of the water increased. As this association became more and more firmly established, the subject fish became conditioned to move up the inclined plane. At the same time, the food chamber was gradually moved upward, day by day, ever farther out of the water. At last the fish learned to go quite out of the water, wriggle into the food chamber, and there wait practically high and dry until food was given, which it then seized sharply, and swam and splashed back to its normal position in the deep part of the tank. There was no mistaking the response. If the fish detected a change of temperature, it went through this remarkable performance; otherwise it did not.

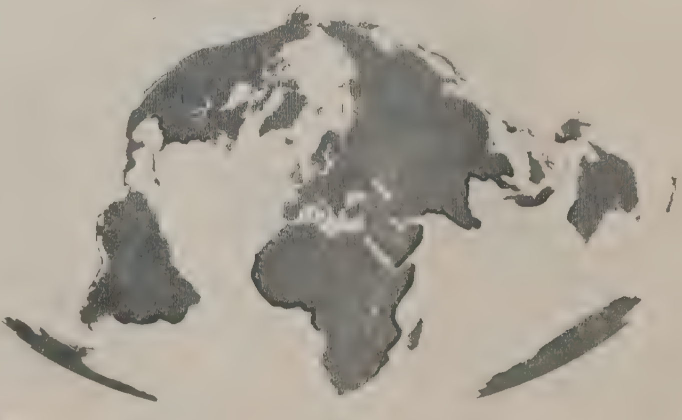
With such experiments, Bull demonstrated that under some circumstances, sea fishes react purposefully to changes in temperature of only 0.03° C., and in salinity of 0.2 parts per thousand. These results indicate the extreme care with which field oceanographic studies must be designed, and the precision with which observations must be made at sea—the figures are close to the limits of accuracy of hydrographic instruments—in order to determine relations between oceanographic conditions and biological effects. They also suggest how some striking changes in marine climate that have been observed in recent years can affect the fish directly. The distribution of marine animals is sharply limited by temperature barriers, as I will illustrate with a few charts:



SARDINES (with mean annual surface isotherms)

Figure IV. A chart showing the distribution of sardines of the world. Sardines are somewhat less closely bound to land masses than are other members of the same family with which we are familiar, namely herring, menhaden and shad. Shad must ascend rivers to spawn; menhaden spawn about estuaries; herring in the intertidal areas; sardines may spawn as far as 200 to 300 miles at sea. Their young come close in, the first months of life along shore. The temperature range of sardines (about 12° to 20° C.) is intermediate between that of the menhaden and that of the herring.

Figure V. A chart showing the distribution of menhaden and similar fishes. In general, these require warmer water than pilchard can tolerate and they occur only in regions with extensive estuarine areas. They spawn in or near estuaries, and their young move into salt water sloughs and marshes and even up into fresh water during their early growing period. Thus the growth and survival of menhaden are more affected by local conditions than many other marine fishes. Inshore conditions of the environment are less stable than are those offshore, hence these fishes are more subject to violent fluctuations.



MENHADEN

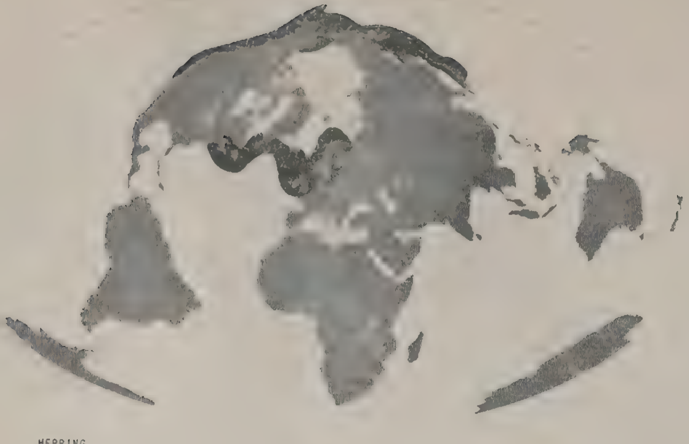


Figure VI. A chart showing th world distribution of herring. Thi is a cold water fish occurring only i the northern hemisphere, north o the range of pilchard.

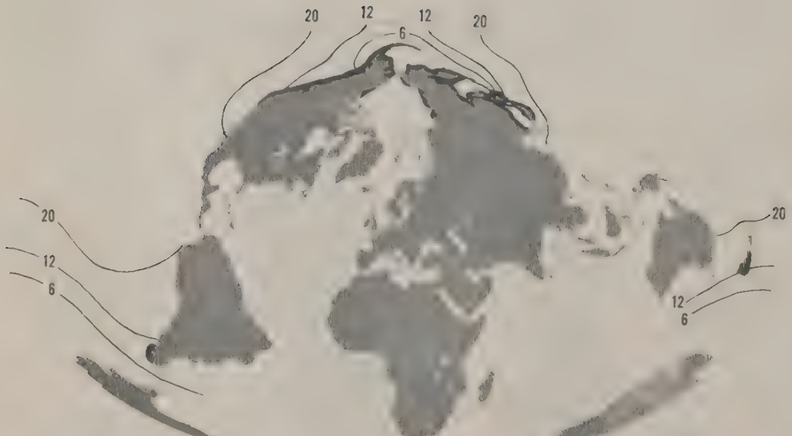


Figure VII. A chart showing the distribution of Pacific salmons. This group of fishes can exist only where there is a peculiar combination of stream conditions and of oceanic conditions, as proved by the fact that although their eggs have been transplanted to many parts of the world, Pacific salmon have taken hold only where environmental conditions approximate those of the North Pacific, i.e., New Zealand, Chile, Maine, New Brunswick. In streams, the optimal temperature conditions for the incubation period are somewhere between 4° and 11° C. Eggs suffer severe mortalities if subjected to excessive periods outside those limits. After hatching, the optimal temperature range which controls the growth and survival of the young lies between 13° and 17° C. Prolonged periods beyond these limits cause excessive mortalities among the young. In the ocean, salmon seem to be limited during their spawning and seasonal migrations to a temperature zone at the surface of about 0° to about 20° C.

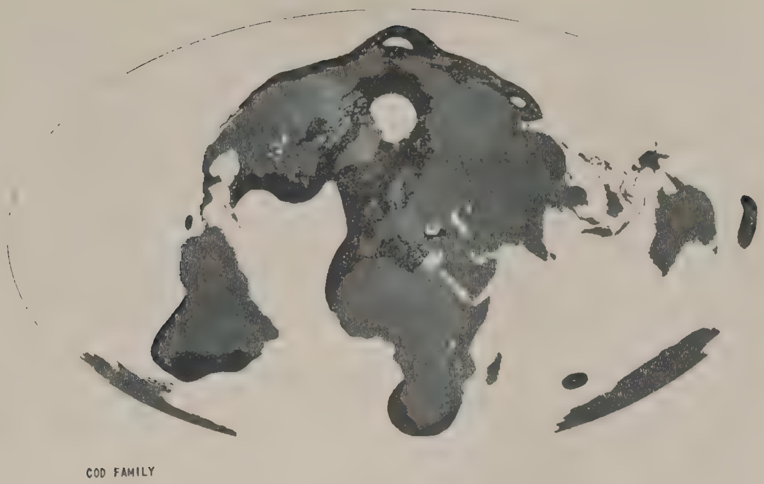


Figure VIII. The cod family which urnishes about 19 percent of the orld's harvest of sea fish is widely istributed on continental shelves in emperate latitudes.

I have shown you that various groups of fishes are confined to certain types of environments and in particular to certain temperature zones. Is there any evidence that there could have been important changes in the location of the boundaries of these zones in recent years that might account for changes in accessibility or abundance of the fishes? In places, yes, as the following charts will show:

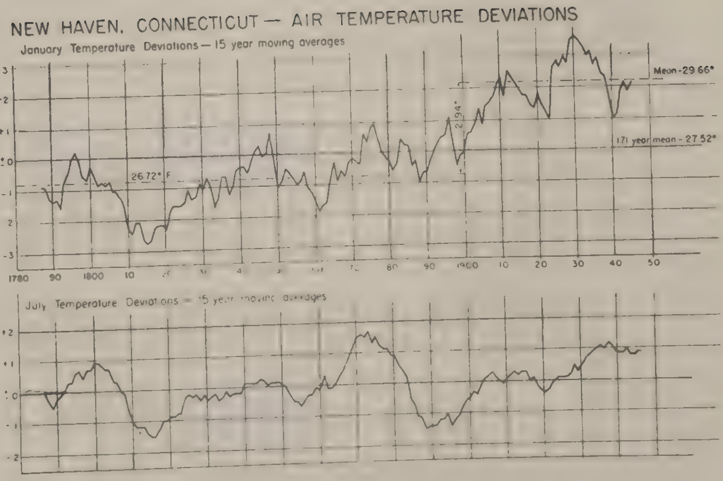


Figure IX. North Atlantic weather as reflected by anomolies in temperature at New Haven. Deviation of average monthly temperature from a 150-year average shows irregular fluctuations and a trend toward warmer winters and summers beginning about 1890 or earlier. Here it has been demonstrated that air temperature and sea surface temperature are positively correlated.

Many European scientists have pointed out evidence that arctic and subarctic areas have been warming, and that there have been pronounced changes in fauna and flora.

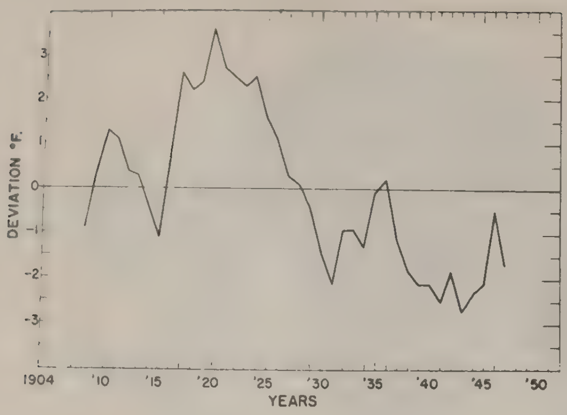
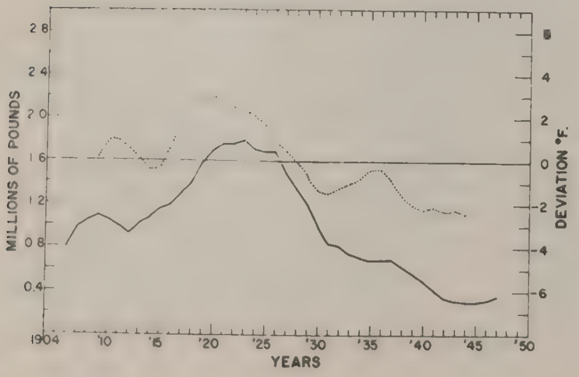


Figure X. The difference between average winter (January) and summer (July) temperatures at the surface of the sea water at Boothbay Harbor, Maine, has decreased since about 1920, indicating an increased mildness of climate. A graph shows annual deviations of these differences from average over the period 1906 to 1947.

Figure XII. Thirty years weather in Rhode Island as indicated by difference between January and July average temperatures. These differences are plotted as deviations from normal. This graph is compared with the commercial catch of lobsters in Rhode Island. This comparison indicates a positive correlation between the catch of lobsters and the degree of difference between January and July temperatures. Rhode Island is near the southern end of the range of lobsters. During a series of years of relatively cold winters in Rhode Island, lobster fishing flourishes; during a series of warm winters, it languishes.



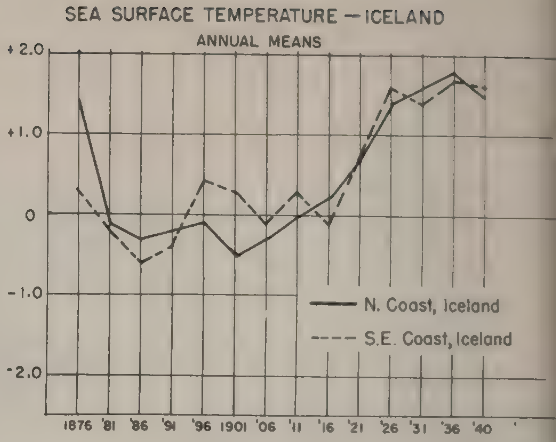
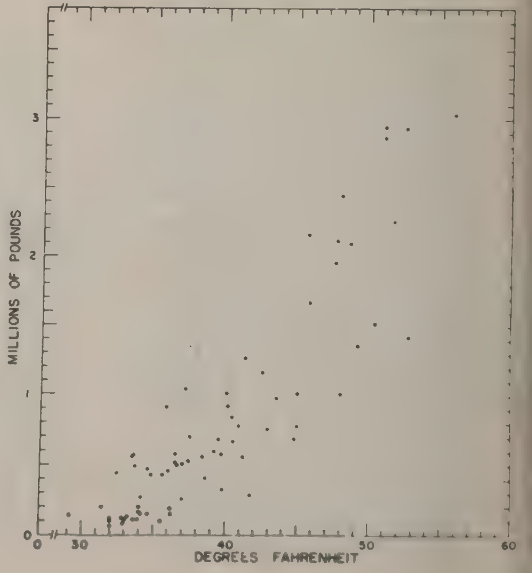


Figure XI. Annual average sea surface temperatures at Iceland have increased during this century, as shown in the following chart.

Figure XIII. The catch of lobsters in Maine, on the other hand, is positively and significantly correlated with the temperature of the surface of the sea water as measured at Boothbay Harbor.

Rhode Island is close to the southern extreme of the geographic range of lobster. The effect of the climatic change was to shift the zone of most favorable conditions toward the north.



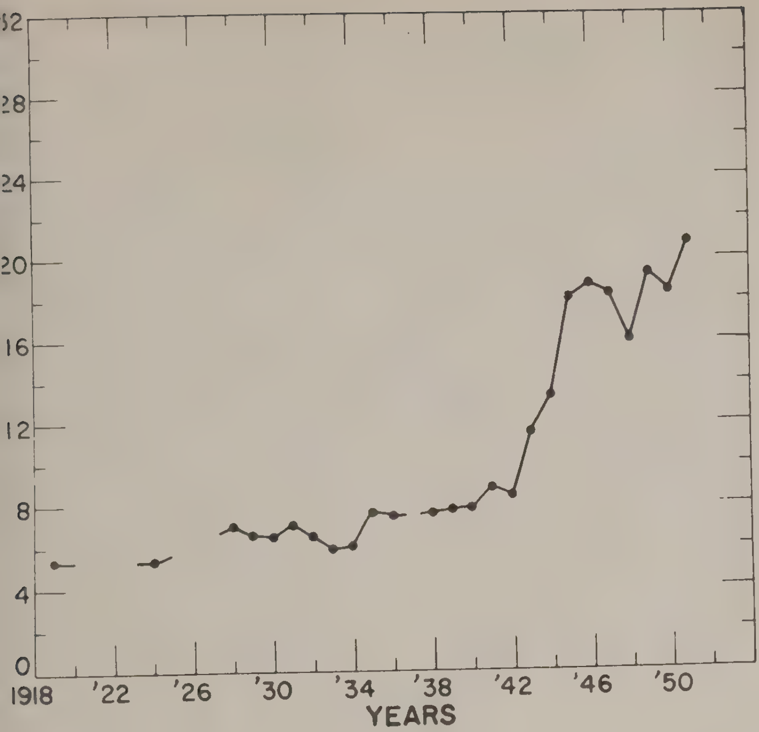


Figure XIV. Commercial catch of bsters in Maine, 1918-51, shows an crease in catch from 8 million ounds to over 20 million pounds.

There are various ways by which limatic changes of this sort might ffect these food fishes. Most directly and simply, they could change the location of the environment having the physical characteristics to which these fishes are physiologically adapted.

If a fish feels uncomfortable because it is too hot, it will move into a cooler zone. This is probably true not only of fishes but of all other classes of animals. Warming encourages invasion by predatory species from warmer zones, and these drive out the former dominating residents. This sort of action may go on all the way along the food chain.

Another effect of changing climate is to stimulate diseases to burst into epidemic proportions. There is mounting evidence that fungi and viruses, which are very sensitive to temperature changes, sometimes severely decimate populations of marine animals and plants.

Striking examples of changing distributions are given by the spread of the mussel parasite and the green crab in the North Atlantic; the northward spread of the cod into the arctic; the return of menhaden to the Gulf of Maine; the shift in composition of the species of shrimps of the Gulf of Mexico, and of shads off the coast of India.

Biologists have been rather slow to become aroused to the possible significance of these changes. Those in countries bordering the Atlantic were first to become interested, perhaps because the effects are more striking in the North Atlantic. Gradually this interest is spreading to other parts of the world, and scientists are beginning to consider the possibility that we are dealing with a world-wide phenomenon.

Proceedings
# of the Fishery Products Conference
at the 47th Annual Convention of the
National Canners Association
January 23–27, 1954

(Reprinted from Convention Issue, INFORMATION LETTER (No. 1472), *January 30, 1954)*

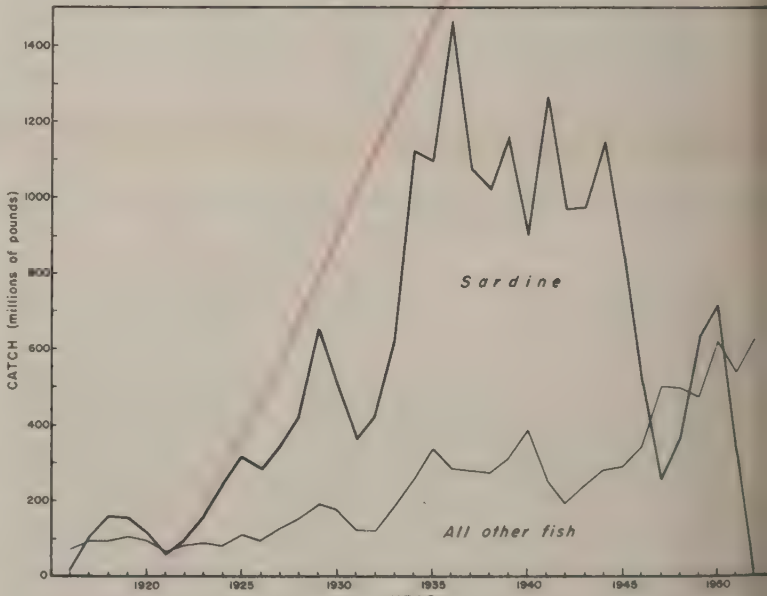
Finally, there are the bacteria which decompose the dead bodies and the excreta of all living creatures, making the constituent substances again available as building materials for the plants. In the sea the same cycle of sunlight, plants, animals and bacteria exists, but with what a difference. Instead of grass there are tiny plants floating in the blue waters, and in place of cows the animals that eat these plants are copepods no bigger than the head of a pin. The tigers that eat the cows are arrow worms and euphausids, only a fraction of an inch in length, and a series of intermediate meat-eaters exists between them and the fish, which represent for us the ocean harvest. Since every link in this long food chain is inefficient, it is not surprising that we reap from the ocean only about 20 million tons of food a year—only a small fraction of the production of our farms on land, and less than a tenth of one percent of the organic production of the sea.

On land, we are used to a great compression of the zone of life. For the most part, it is confined to a thin surface layer a few tens of feet thick. But the whole giant volume of the sea is the theater of life. Even in the great depths seven miles below the surface, where no light penetrates, the temperature is always just above freezing, and the pressure is more than 15,000 pounds per square inch, recent oceanographic expeditions have found scores of different species, and the bottom muds at these depths teem with bacteria. But the plants of the sea, on which all other living things depend, grow only in the waters near the surface where bright sunlight penetrates. These subsurface waters differ widely in fertility. Like the land, the ocean has its green pastures, where life flourishes in abundance, and its deserts where a few poor plants and animals barely survive. Unlike the rich soil of Iowa, which remains nearly constant in fertility from year to year, even the most productive ocean areas sometimes drastically decline in a relatively short time. After a period of years they may with equal abruptness apparently recover their fertility.

The fertility of the land depends primarily on four things: air temperatures throughout the year; the intensity of sunlight during the growing season; the amount of water; and the presence of a sufficient amount of plant nutrients in the soil—that is, substances such as phosphate and nitrate and many others, which usually occur in very small amounts but are essential for plant growth. We can easily see the importance of all these factors by contrasting the luxuriant growth of a tropical sugar cane field, where the temperatures are warm throughout the year, the rainfall is abundant, and the soil is supplied with plant nutrients by fertilization, with the sparse growth in a dry desert or on the cold Arctic tundra, or on the rocky, glaciated, virtually soilless hills of New England.

In the sea, water is of course always abundant, the plants are well adapted to the relatively narrow range of temperature; and the intensity of sunlight determines the length of the growing season and the depth to which plants can grow, but apparently not the differences in fertility. These depend only on the plant nutrients present in the waters near the surface. As with any well-worked soil on land, these plant nutrients must be replenished each year. They are always being depleted by the slow sinking of plant and animal remains from the brightly lighted subsurface waters into the dark waters of the depths. Men plow the soil to restore its fertility by bringing up to the surface the plant nutrients which have been carried downward in solution. Similarly, the fertility of the sea is restored when the nutrient-rich deep waters are brought up near the surface. This "plowing of the sea" must be carried out on a very large scale and can only be accomplished by the ocean itself. The regions where the ocean plowing is most effective are the green pastures of the sea.

The ocean plowing is accomplished in one of three ways. In some regions the wind drives the surface waters away from the coast, or away from an internal boundary in the sea, and nutrient-rich water wells up from mid-depths. In other areas the surface waters are cooled near to freezing in the wintertime, become heavy and sink, and mix with the nutrient-rich deep waters. Elsewhere, violent turbulence occurs along the boundaries between major ocean currents, and some of the nutrient-rich deep waters are thereby brought into the brightly lighted zone where the nutrients can be used by the plants. As Sverdrup has pointed out, most of the great fisheries of the world depend for their existence on one or another of these three ways in which the ocean plows itself. The sardines, anchovies and mackerel of California, the sardines of South Africa, the tunas off the West Coast of North and South America, the bonitos, albacore and hake of Chile and Peru, the apparently abundant deep tunas in the equatorial zone of the Pacific, all live in regions of up-welling, where the deep water is pumped to the surface by the wind.



1. From 1922 to 1946 The Catch of Pacific Sardines Exceeded in Weight That of All Other California Fisheries Combined. (California Marine Research Committee Annual Report.)

Reprinted from SCIENCE, June 11, 1954, Vol. 119, No. 3102, pages 850–851.

e Spectrum of Magnesium in ncentrated Sulfuric Acid

iemann and Ikawa (*1, 2*) have shown that the e and amount of a carbohydrate in solution can be nd from its spectrum in the 210 to 400 mμ region strong mineral acid. In some cases, a quantitative ermination of one monosaccharide can be made in admixture of other monosaccharides, and some ysaccharides can be resolved into their component nosaccharide units. These determinations are based the production of various furfurals by the monocharides on heating in strong mineral acid, each ss of monosaccharides condensing into a slightly ferent furfural.

n crude preparations of carbohydrates, taken from water by extraction on charcoal, alumina, and ner adsorbents, a discrepancy of 4 to 5 mg/liter in total of 20 to 25 mg/liter was noted between the nounts of carbohydrates found by examination of sulfuric acid spectra in the 210 to 400 mμ region d those found by the N-ethylcarbazole method. Since th methods depend on the formation of a furfural concentrated sulfuric acid, it was apparent that me compound or compounds other than carbohyates, could produce ultraviolet spectra similar to ose of the furfurals, in hot sulfuric acid.

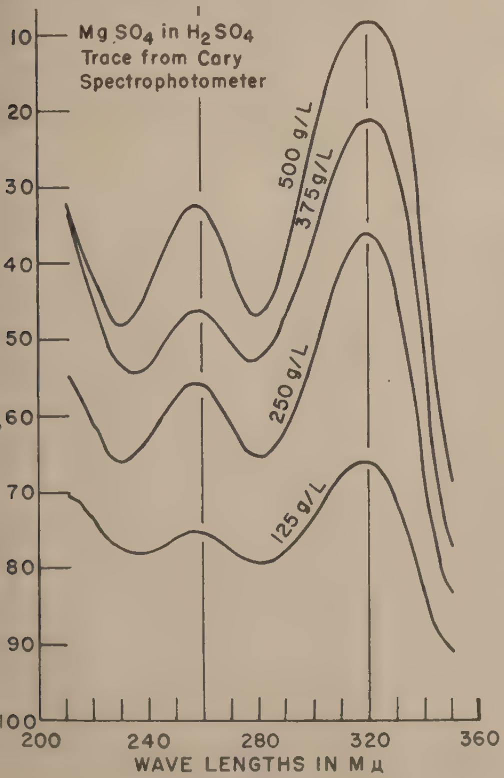


Fig. 1.

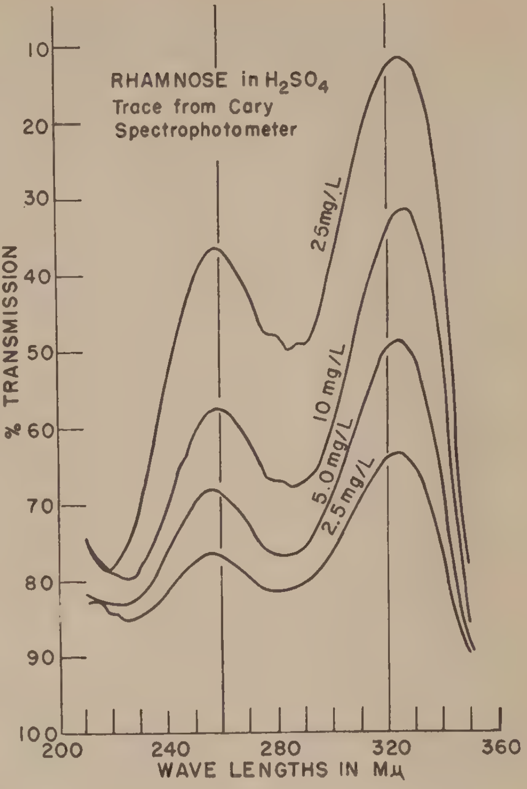


Fig. 2.

By a process of elimination, the substance was found to be magnesium. Figures 1 and 2 show the close correspondence between the sulfuric acid spectra of high concentrations of magnesium sulfate and those of a methyl pentose, rhamnose. Certain polysaccharides and some mixtures of monosaccharides duplicate even more closely the spectrum given by magnesium. While the concentrations of magnesium sulfate necessary to give these spectra may seem absurdly high, in working with crude preparations in which the carbohydrate concentration is very low, concentrations of magnesium of this order may occur. The normal concentration of magnesium in sea water is about 1.3 g/liter. However, magnesium is picked up very readily by a great number of adsorbents and concentrated easily to 50 or 100 times its normal concentration. Exceedingly thorough dialysis is necessary to remove all traces of magnesium.

PETER J. WANGERSKY

U.S. Fish and Wildlife Service
Fort Crockett, Galveston, Texas

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Received January 18, 1954.

from COPEIA, 1954, No. 1, pp. 29–32, February 19
U.S.A.

finitions and Derivations of Various Common Measures of ortality Rates Relevant to Population Dynamics of Fishes[1]

T. M. Widrig

HOUGH various measures of mortality ates have been used to estimate popula- zes, and the effects of fishing on stocks es, the applications in the literature contain derivations and definitions of rameters estimated. When these are in- , there is a marked lack of consistency in tation used for identical parameters. See, mple, Baranov (1918), Ricker (1940) and on and Holt (In press).

e of the parameters are definitions and are derived from the defined parameters. lly the difference between a definition and ivation is that the derivation involves n assumptions made during its develop- from definitions.) The arguments leading ese derivations are lacking or widely red in the literature.

s my intention, then, to gather in one the definitions and derivations, to present gical basis for the derivations, and to l some of the notations used for these and parameters by other workers. Surely some ard should be adopted. The notation used s paper is fairly complete and easy to type; ose it as a standard.

Definitions

STANTANEOUS (INDEPENDENT) RATES".— endence, in this paper, means that a given ality rate is not influenced by the magni- of other mortalities occurring during the period.

ishing acts such that the ratio of the catch umbers) of a fishery is directly propor- l to the available stock, during an instant ne, we have

$$\frac{dC}{dt} = pN_t$$

e "C" is the catch, "N_t" is the stock, and s the rate of fishing.

the death rate of fish from all other causes eeds in the same fashion, the deaths in an instant being proportional to the stock in that instant, then

$$\frac{dB}{dt} = qN_t$$

where "B" is the number of all other (natural) deaths, and "q" is the rate of natural death.

The rate of total death, then, is the sum of the independent rates of mortality:

$$\frac{dD}{dt} = \frac{dC}{dt} + \frac{dB}{dt} = (p + q)\,N_t = iN_t$$

where "i" is the rate of total death and "D" is the total number of deaths from all causes.

"Annual (dependent) rates"—conditional.—Conditional, as used here, means that the simple sum of this measure of the components of total mortality is not equal to the corresponding measure of total mortality rate.

Over the period of a year, or of a season,

$$m = \frac{c}{N}$$

where "c" is the number of fish that would be caught *if* the only deaths occurring were those due to fishing. "N" is the size of the stock at the beginning of that period, and "m" is the rate of fishing.

Similarly,

$$n = \frac{b}{N}$$

where "b" is the number of fish that *would* die naturally *if* the only deaths occurring were those due to natural causes, and where "n" is the rate of natural mortality.

"Annual (dependent) rates"—unconditional.—The "rate of exploitation" is "u" in

$$u = \frac{C}{N}$$

where "C" is the number of fish that die from fishing, although natural mortality may be going on at the same time ("C" is simply the catch).

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The rate of natural mortality is “v” in

$$v = \frac{B}{N}$$

where “B” is the number of fish that die naturally although fishing may be going on at the same time.

The rate of total mortality is “a” in

$$a = \frac{D}{N}$$

where $D = C + B$.

Included above are the defined parameters. Those given below are derived from these definitions and require, during the derivations, certain assumptions about the time and space distribution of the defined parameters. These assumptions are included at the appropriate places.

DERIVATIONS

All the foregoing *dependent* mortality rates may be expressed in terms of the instantaneous (independent) rates as follows:

The total deaths, “D”, may be evaluated in terms of the instantaneous rate, “i”, by integrating the expression for the rate of accumulation of “D” over the time period for which one wishes to express the total death count. By definition, this total death count, expressed as a fraction of the initial population of the time period, is equal to “a”.

Since

$$\frac{dD}{dt} = iN_t$$

$$= i(N - D_t)$$

So

$$\frac{dD}{(N - D_t)} = i(dt)$$

Now if “i” is constant during time “t”,

$$(1) \qquad it = \int_0^D \frac{dD}{(N - D_t)}$$

and upon integration, $e^{-it} = (N - D_t)K$, where K is a constant. When $t = 0$, $e^{-it} = 1$, and $D_t = 0$, so $(N - 0)K = 1$, or $K = \frac{1}{N}$

(1) becomes

$$e^{-it} = (N - D_t)\frac{1}{N}$$

or

$$D_t = N(1 - e^{-it})$$

Since by definition

$$a_t = \frac{D_t}{N}$$

we have “a” in terms of “i”:

$$a_t = 1 - e^{-it}$$

Since the stock at an instant is the same a the initial stock less the “D_t”, we also hav the expression for the stock size on time a

$$(2) \qquad N_t = Ne^{-it}$$

if “i” is constant during time “t”.

This will be useful in the derivations t follow.

If fishing is the only cause of death, we hav

$$\frac{dc}{dt} = pN$$

and if “p” is constant over time “t”,

$$c = (1 - e^{-pt})N$$

from an argument identical to the derivatio of “D”.

Similarly

$$b = (1 - e^{-qt})N$$

if “q” is constant over time “t”.

These two expressions give the relation be tween “p” and “m”, and “q” and “n”: since by definition,

$$m = \frac{c}{N}$$

then

$$m_t = 1 - e^{-pt}$$

and $n = \frac{b}{N}$, so $n_t = 1 - e^{-qt}$, if “p” and “q are constant over time t.

The rates of dependent mortality can be ex

d in terms of the instantaneous rates as
s:

$$\frac{dC}{dt} = pN_t$$

$$N_t = e^{-it}$$

$= \frac{p}{i}(1 - e^{-it})N$ for “t” from “0” to “1”,
integration. Since, by definition,

$$u = \frac{C}{N}$$

$$u = \frac{p(a)}{i}$$

nally, a very simple but very basic deriva-
is one regarding the derived proportionali-
of fishing effort and the instantaneous fish-
mortality rate. The latter has been defined
ve as

$$p = \frac{\frac{dC}{dt}}{N_t}$$

hus it is the fraction of the population, at
nstant of time, that is caught by the total
ing effort at that instant. Now in an in-
nt, we may safely assume that the several
ts of fishing effort do not physically com-
e or entangle each other's gear, so each unit
ffort should contribute equally to p, provid-
the unit of effort is taken as a standard,
h the idea of equality in mind. Then each
t of such effort should have a ratio of catch
an instant to the stock in that instant of,
, Q, such that

$$p = Qf$$

ere f is the number of standard fishing effort
its. The assumption of Q being the same for
h unit of effort can be substantially satisfied
such devices as comparing the performance
the several units of fishing effort, such as
ats, during a season, when these units of
ort are fishing the same stock density. Then,
Q is constant, the effective p to be expected
m any size of f is predictable—a very useful
uation in examining past fishing as well as predicting what to expect in the way of catches in the future.

Similarly for “B”,

$$\frac{dB}{dt} = qN_t = qNe^{-it}$$

So

$$B = N\frac{q}{i}a$$

after integration for t from “0” to “1”, and since, by definition,

$$v = \frac{B}{N}$$

then

$$v = \frac{q}{i}a$$

Assumptions necessary to the above derivations are that p, q, and i, be constant during the time that the deaths are occurring. If these rates are not constant, the resulting relations are different, of course, from those here derived. However, the instantaneous rates are seldom measured directly, but are deduced from the death counts. Therefore, the use of the above relations gives estimates of the instantaneous rates that would, if constant, yield the observed annual death rates. In a sense, then, the constant rates assumed to obtain will be average (or effective) instantaneous rates, or equivalent instantaneous rates, in the case when they are actually not constant during the time interval considered.

DISCUSSION

ESTIMATION.—In most fisheries, the only parameter that can be observed directly is the rate of exploitation, “u”, and then only where the initial stock is known. The procedure of tagging or marking a number of fish and then observing them as they reappear in the catch is a common means of estimating (observing) “u” directly, since one then knows what the initial marked population is.

It is interesting that “p” can be shown to be equal to

$$p = \frac{C}{\bar{N}}$$

TABLE I

NOTATION BY SOME FISHERIES WORKERS IN POPULATION DYNAMICS

Widrig (1954)	Ricker (1944)	Baranov (1918)	Beverton & Holt (In Press)	Clark (1945)	Thompson (1950)	DeLury (1947)	Schuck (1949)	Fry* (1949)	Russell (1942)	Herrington (1948)
p	p	k_1	F	..	..	d	..	..	..	..
q	q	k_0	M	..	..	..	..	r	..	..
i	i	k	..	..	..	..	..	..	..	..
u	μ	..	..	..	..	..	..	..	..	..
m	m	ϕ_1	..	F	..	..	..	..	..	..
v	ν	..	..	..	..	..	..	..	..	..
n	n	ϕ_0	..	N	..	..	..	..	..	..
a	a	ϕ	..	T	..	..	..	..	..	..
s	s	..	..	..	R	..	..	..	..	..
b	..	..	..	..	..	..	..	..	..	..
B	..	..	..	..	..	..	N	R	M	M_n
c	..	..	..	..	..	..	..	..	..	..
C	..	..	..	..	C	c, K	C	..	C	M_f
D	..	..	..	..	..	..	..	D	..	..
N_t	N_t	..	...	..	..	..	..	..	..	..
N	N_0, N	n	..	..	A, S	N(0), N(1) N	S	..	S_1	P_1
$\bar{N}$	$\bar{N}$	..	..	..	..	..	..	..	..	..
f	f	..	..	..	f	e, E	..	..	..	..
Q	..	..	..	..	r	k	..	..	..	..
C/f	..	..	..	..	c	C	..	..	..	..

* Same as DeLury, except as noted here.

where "C" is the catch, and $\bar{N}$ is the *average*, not initial, stock during the time period considered.

Also

$$\frac{C}{p} = \bar{N} = \frac{C}{Qf}$$

So

$$\frac{C}{f} = Q\bar{N}$$

Since the instantaneous rates are independent of each other, they are convenient to use. But since the average population is difficult to observe, "p" will seldom proceed directly from observational data.

Although "a", "u", and "v" have rather good intuitive implications, it is difficult to observe "m" and "n", in practice.

The following table compares the notation used here with a sample of that used by others. The list is by no means complete, but illustrates the diversity of notation for identical parameters.

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